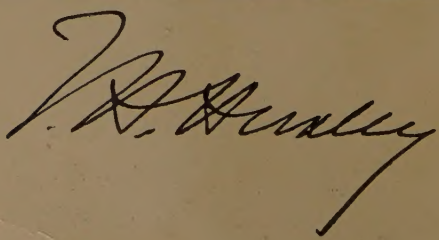
HUXLEY'S AUTOBIOGRAPH AND ESSAYS

SIMONS

TWENTIETH CENTURY TEXT-BOOKS



TWENTIETH CENTURY TEXT-BOOKS

AUTOBIOGRAPHY AND SELECTED ESSAYS

BY

THOMAS HENRY HUXLEY

EDITED WITH INTRODUCTION AND NOTES BY

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PREFACE

THE selections in this volume are convincing illustrations of Huxley's dictum that "science and literature are not two things, but two sides of one thing." They offer splendid examples of the correlation of science and English; they show how the facts of science can be made attractive through the method of treatment; they emphasize the necessity for clear exposition in order to impress knowledge. The matter presented is interesting; the manner of presentation is clear, direct, literary. Hence the study of these selections should give both knowledge and power. Few better models of expository and argumentative writing can be put into the hands of pupils.

I wish to express my thanks to Mr. A. T. Stuart and Mr. P. M. Hughes, Superintendent and Assistant Superintendent, respectively, of the public schools of the District of Columbia, for their generous support and encouragement in the editing of these essays.

S. E. S.

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INTRODUCTION

SKETCH OF HUXLEY'S LIFE

Birth.—Thomas Henry Huxley, the seventh child of George and Rachel Withers Huxley, was born, as he was fond of saying, "on the seventh day of the week, in a seventh floor back," May 4, 1825, at Ealing, now a suburb of London, but then a quiet little village. Genius for work he inherited from his mother, who got things done while others were discussing them, and who, her son used to say, would have been leader of the Opposition in the House of Commons had she been a man. From his father Huxley inherited his inborn faculty for drawing, his hot temper, and his tenacity of purpose. Huxley's father was senior assistant master of the semi-public school at Ealing for many years, but when Thomas was ten years old went back to his native town, Coventry, to become manager of the Coventry savings bank.

Early Education.—The removal of the family to Coventry caused the withdrawal of Thomas from the Ealing public school which he had attended for two years. From this time on his school training was most irregular. He was a great reader, and browsed for hours every day in his father's library. He always had a wonderful faculty "for tearing out the heart of a book," but—and perhaps for this very reason—had a poor verbal memory. He could never quote exactly.[1] At an early age science in-

[1] There is hardly an instance of exact quotation in the selections in this volume.

terested him. "When a boy of twelve," his son and biographer[1] tells us, "he used to light his candle before dawn, pin a blanket around his shoulders, and sit up in bed to read Hutton's Geology." His passionate love for sincerity and his intense hatred of make-believe he always traced to his early reading of Thomas Carlyle. *Sartor Resartus* (The Tailor Re-patched)—Carlyle's famous satire, professing to be an exposition of the new philosophy of clothes, but really teaching the doctrines of truthfulness, work, and, above all, hatred of sham—was literally at this period Huxley's Bible. And it was Carlyle who led Huxley to the study of the German language and literature. During these years Huxley also taught himself French and Italian. At the age of fifteen he began to keep a fragmentary journal, which he entitled *Thoughts and Doings*. Here he jots down any striking thought or saying he has come across in his reading; speculates on the causes of things; discusses the right or wrong of existing institutions; and comments on the value of scientific experiments for correcting his theories—habits of thought which stuck by him all his life.

Medical Education.—When Huxley was sixteen years old he began the study of medicine by becoming assistant to a Dr. Chandler, whose practice took him into the slums of East London. Soon after, he went to his brother-in-law, Dr. J. G. Scott, in the north of London, and while working under him, attended regularly the lectures at Sydenham College. He was a good student, and his toil was rewarded by his appointment as Free Scholar at Charing Cross Hospital, October 1, 1842. Here he won dis-

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[1] Huxley, Leonard. *Life and Letters of Thomas Henry Huxley*, Am. ed., 2 vols. This is the source to which the writer is indebted for most of the facts presented in this sketch.

tinction in anatomy and physiology, receiving a gold medal for his work in these subjects when he took the degree of M. B. (Bachelor of Medicine) at London University in 1845.

Later Education.—But his education was only just begun. He was a student all his life. The last entry in his journal, dated December 31, 1856, reads: "1856-7-8 must still be 'Lehrjahre' (student years) to complete training in principles of Histology, Morphology, Physiology, Zoölogy, and Geology by *Monographic Work* in each Department; 1860 will then see me well grounded and ready for any special pursuits in either of these branches. . . . . In 1860 I may fairly look forward to fifteen or twenty years 'Meisterjahre' (independent work)." He began the study of Greek late in middle life, so that he could read Aristotle and the Greek Testament in the original. Throughout his life each day brought its work, even after his retirement from government employment. Up to his last illness there was always something waiting for his hand—an unfinished lecture, a magazine article, or a new monograph.

In the Navy.—Shortly after graduation, Huxley was appointed Assistant Surgeon in the Navy, and assigned to H. M. S. *Rattlesnake,* which was detailed for marine survey service in Australian waters. It was understood that he was to do scientific work on the expedition. Just how he came to enter the Navy is characteristically told in his *Autobiography.* The vessel sailed December 3, 1846, and the voyage lasted almost four years. About eleven months were spent in Sydney, and it was while there that he met Miss Henrietta Anne Heathorn, who later became his wife. It was while on this expedition that he began in earnest his contributions to science by a paper on the Medusæ (jellyfish) which was published by the Royal Society dur-

ing his absence.[1] Four years after his return, when he found there was no hope of getting government aid in the publication of his scientific treatises, he severed his connection with the Navy by deliberately refusing to obey orders when detailed to the ship *Illustrious*. His name was, of course, stricken from the rolls.

Life Work.—And then began the search for congenial work. Finally, after several vain attempts to secure university work, he received the appointment of Lecturer on Natural History in the Government School of Mines, and also of Naturalist to the Geological Survey. A little later he began to teach in the Royal College of Surgeons, with which institution he was connected most of the rest of his life. He speaks rather humorously in his *Autobiography* of the first appointment offered him: "At last, in 1854, on the translation of my warm friend Edward Forbes to Edinburgh, Sir Henry de la Beche, the Director-General of the Geological Survey, offered me the post Forbes vacated of Paleontologist and Lecturer on Natural History. I refused the former point blank, and accepted the latter only provisionally, telling Sir Henry that I did not care for fossils, and that I should give up Natural History as soon as I could get a physiological post. But I held the office thirty-one years, and a large part of my life work has been paleontological."

Marriage.—It now became possible for him to marry, especially as Miss Heathorn's parents had recently brought her to England for her health. The long engagement was brought to a happy close July 21, 1855. He writes his friend, Sir Joseph Hooker, of the coming event in his characteristically humorous way: "I terminate my Bacca-

[1] In his *Autobiography*, Huxley tells us that he published his first scientific paper in the *Medical Gazette*, 1845.

laureate and take my degree M. A. trimony (isn't that atrocious?) on Saturday, July 21."

When Darwin heard that Huxley was to be married he said to him: "I hope your marriage will not make you idle; happiness is not, I fear, good for work." His fears were not realized, however. Huxley's married life proved the error of his views. No more successful marriage than Huxley's, in point of view of both domestic happiness and professional achievement, is known in the annals of literary or scientific history. Some years afterwards, indeed, his friend Dr. Anton Dohrn, after visiting Huxley at the little town of Swanage, wrote: "If I had to give anybody a definition of this much-debated word [happiness], I should say, Go and see the Huxley family at Swanage; and . . . you [will] feel what is happiness and never more ask for a definition of this sentiment." (There were seven children in the Huxley family at this time.)

Ideals.—From this time on Huxley's life was a busy one. He saw life steadily and saw it whole. There was much to do and he forged ahead, "ohne Hast aber ohne Rast" (without haste but without rest).[1] Work was his gospel. Every day was with him a working day. His regular duties as lecturer before the students of the Government School of Mines in Jermyn Street began at nine o'clock. Between classes he made researches in the laboratories in physiology and biology. At night he often spoke before working men or learned societies; and after he reached home he always spent two or three hours in his library, working up into lectures or scientific papers the results of studies and researches made in the laboratory. "I sometimes thought he had no higher happiness than

[1] Goethe, *Zahme Xenien*, II.

work," says his friend Mr. George W. Smalley. "He would dine on a little soup and a bit of fish; more than that was a clog on his mind. 'The great secret,' he said, 'is to preserve the power of working continuously sixteen hours a day if need be. If you cannot do that, you may be caught out any time.'" As early as 1850 he wrote his favorite sister Lizzie: "I don't know, and I don't care whether I shall ever be what is called a great man. I will leave my mark somewhere, and it shall be clear and distinct—

T. H. H. his mark—

and free from the abominable blur of cant, humbug, and self-seeking which surrounds everything in this present world." And in the last entry to his Journal, December 31, 1856, he thus sums up his aims: "To smite all humbugs, however big; to give a nobler tone to science; to set an example of abstinence from petty personal controversies, and of toleration for everything but lying; to be indifferent as to whether the work is recognized as mine, so long as it is done." Huxley had found his work, and faithful to the family motto, *tenax propositi* (tenacious of purpose), he did it.

Defense of Darwin.—The publication of Darwin's *Origin of Species* in 1859 was an important event in the life of Huxley, for he immediately became the eloquent and earnest expounder of Darwin's theory of evolution, both to the scientific and to the popular world. He once jokingly said to Darwin that he would have written the *Origin of Species* himself if Darwin had been a little more of a gentleman and held off for a few years. The defense began in 1860 with the famous debate between Huxley and Bishop Wilberforce, at the meeting of the British Association for the Advancement of Science at Oxford,

and occupied much of Huxley's time for many years. So perfect was his exposition to working men, that Darwin wrote Huxley after reading these lectures: "I have read No. IV and V. They are simply perfect. They ought to be largely advertised; but it is very good in me to say so, for I threw down No. IV with this reflection, 'What is the good of my writing a thundering big book, when everything is in this green little book, so despicable for its size?' In the name of all that is good and bad, I may as well shut up shop altogether." It is interesting to note that Huxley's last appearance before the public was at the meeting of the British Association at Oxford, just thirty-four years after his famous encounter with Bishop Wilberforce. This time he received an ovation.

American Visit.—In the summer of 1876 Huxley came to America to deliver the inaugural address at the opening of the Johns Hopkins University. His wife accompanied him, and he always called this his second honeymoon. He was welcomed with enthusiasm wherever he went. Says his son: "His writings had made him known far and wide . . . the very miners of California read his books over their camp fires; and his visit was so far like a royal progress that unless he entered a city disguised under the name of Jones or Smith, he was liable, not merely to be interviewed, but to be called upon to 'address a few words' to the citizens." Besides the *Address on University Education,* delivered at Johns Hopkins, September 12, Huxley gave three lectures on *Evolution* in New York City, just before sailing for home. These American addresses are among the most interesting of his popular lectures.

Popularization of Science.—In 1855 Huxley gave his first lecture to working men. He thus began his work in the popularization of science—a work continued for over

thirty years. Much of his time was spent in the lecture room. His attempts to bring the truths of science home to men's business and bosoms did not, however, stop with the lecture room. The printing press was called to the aid of the new learning. Huxley was a regular contributor to *Contemporary Science.* In 1858 a scientific column was started in the *Saturday Review* through the influence of Huxley, Hooker, and Tyndall, and it was largely due to Huxley's efforts that the *Natural History Review* was founded in 1860.

Evidence as to Man's Place in Nature, Huxley's first book, was published in 1863. Here he demonstrates that man is a development from the lower forms of life. This doctrine at that time was rank heresy. Huxley was warned by his friends not to publish it for fear of ruining his career. True to his convictions, however, he went ahead and published the volume, for he felt that he had found the truth and must spread it. A collection of Huxley's lectures to the people and addresses before scientific societies was published in 1870 under the title *Lay Sermons, Addresses, and Reviews.* In 1871 Huxley and two of his colleagues undertook the joint editorship of a series of *Science Primers* for Macmillan. Thus, throughout his life, Huxley's great effort was to interpret nature to man in terms of simplicity. It was his aim to resolve the beauty and the mystery of the natural world into knowledge, at the magic touch of science.

Other Interests.—Huxley's interests were wide, his sympathies broad. He was a lover of music, art, and literature. His favorite modern poet was Tennyson. In a letter to Tyndall, dated October 15, 1892, he speaks of Tennyson as the first poet since Lucretius who has understood the drift of science. And again he declared that Tennyson's insight into the scientific method as shown in

In Memoriam was equal to that of the greatest experts. Huxley's house was a rendezvous for the literary and artistic, as well as the scientific, elect of London.

Huxley was a member of two famous London clubs, the X Club and the Metaphysical Society. The X Club was founded at his suggestion. He gives the following account of how it got its name: "At starting, our minds were terribly exercised over the name and constitution of our society. As opinions on this grave matter were no less numerous than the members—indeed more so—we finally accepted the happy suggestion of our mathematicians to call it the X Club; and the proposal of some genius among us that we should have no rules save the unwritten law not to have any, was carried by acclamation." It was composed exclusively of men of science. There were nine members, among them, John Tyndall, Herbert Spencer, Sir John Lubbock, and Sir Joseph Hooker. They met and dined together the first Thursday in every month, except during the summer. The club lasted from 1864 to 1892. In all there were two hundred and forty meetings. The last was held in March, 1892; thereafter no more, for, as Sir Joseph Hooker then said to Huxley, "At our ages clubs are an anachronism."

The members of the Metaphysical Society were drawn from many fields—the political, the literary, the philosophical, the theological, the scientific, and included such men as Gladstone, Tennyson, John Morley, John Ruskin, Frederic Harrison, Dean Stanley, and Sir John Lubbock. Huxley often crossed swords with Gladstone at its meetings and always retired covered with glory.

Death.—Huxley's health was never robust. His constitution was weakened by an attack of blood poisoning when a mere boy. It was his habit all through life to take long walking tours through England and Switzerland for his

health; in spite of this, his friends insisted that he never got enough daily out-of-doors exercise. In 1872 he had a complete breakdown, and through the generosity of eighteen friends was enabled to make a tour of three months' duration through Egypt in search of health. In a year his health was fairly restored, and he was back again at the workshop, turning out, if possible, more than ever. In 1884 he had another breakdown, and in 1885 he retired from government service after thirty-one years of faithful work, and was granted a pension. Retirement with him, however, did not mean "rusting out"; he put ten more years of work to his account. In 1889 he decided to move from London to Eastbourne, by the sea. Here he built a villa which he called Hodeslea, "which is as near as I can go to Hodesleia, the poetical original shape of my very ugly name," he confessed. In 1891 he took up gardening, in which he became much interested, and from then on to the end, his time was occupied with gardens, grandchildren, and books. In March, 1895, Huxley had an attack of bronchitis, from the effects of which he never recovered. Three months afterwards, June 29, he died, at the age of seventy. He was buried at Finchley, beside the body of his oldest son who had died thirty-five years before. On his tombstone were engraved, at his request, the following lines from a poem by his wife:

> "Be not afraid, ye waiting hearts that weep;
> For still He giveth His belovèd sleep,
> And if an endless sleep He wills, so best."

His wife still lives (1910), and in the summer of 1909 this charming, active little woman of eighty-six was one of the most interesting as well as one of the most interested figures at the great Darwin Centenary, celebrated at Cambridge University.

Honors.—During his lifetime Huxley was not without honor in his own country and in foreign lands. He received ten honorary degrees from the greatest universities of the world: from Oxford, Cambridge, London, Edinburgh, Aberdeen, and Dublin at home; from Breslau, Würzburg, Bologna, and Erlangen abroad. He was a member of sixteen scientific societies in London alone; of twelve in Germany; of eight in America; and of others in India, South America, and Africa. He served on ten Royal Commissions; he was Secretary of the Royal Society for almost ten years, and he received the greatest honor in the gift of the scientific world when he was made President of the Royal Society in 1883. His contributions to science were acknowledged by the Royal Society through the award to him of the Royal Society's medal in 1852; the Copley medal in 1888; and the Darwin medal in 1894.

APPRECIATION OF HUXLEY'S WORK

Huxley's Place in the Intellectual Life of His Times

"The emancipation of thought—that is Huxley's legacy to this [nineteenth] century," says his friend Mr. Smalley. Influenced by Carlyle, Huxley early dedicated his life to the exposure of shams and the revelation of truth. Always a bitter enemy of error, he took an aggressive part in the scientific and educational controversies of his day. Huxley fought a brave fight for freedom of thought. He conducted a consistent campaign against tradition and authority when in conflict with the onward march of ideas. His aim was the betterment of mankind through the advancement of learning. He did not attack the Bible, but the applications made of it and the

implications read into it. "The Bible has been the *Magna Charta* of the poor and oppressed," he declared; "nowhere is the fundamental truth that the welfare of the State, in the long run, depends on the uprightness of the citizen, so strongly laid down. Assuredly the Bible talks no trash about the rights of man; but it insists on the equality of duties, on the liberty to bring about that righteousness which is somewhat different from struggling for 'rights,' on the fraternity of taking thought for one's neighbour as oneself." Huxley had a deeply religious nature. He ever felt that reverence for the unknown in which lies the essence of all religion. His fight was not against religion, but against clericalism—that clericalism which was the deadly enemy of science, which denounced every person and every thought connected with evolution. "The antagonism between science and religion appears to me," he declared, "to be purely factitious, fabricated on the one hand by short-sighted religious people; on the other by equally short-sighted scientific people." And again, "The antagonism of science is not to religion, but to the heathen survivals and the bad philosophy under which religion herself is often well-nigh crushed."

In a letter to his wife, written at Baden, 1873, Huxley says: "We are in the midst of a gigantic movement greater than that which preceded and produced the Reformation, and really only the continuation of that movement. But there is nothing new in the ideas which lie at the bottom of the movement, nor is any reconcilement possible between free thought and traditional authority. . . . I have no more doubt that free thought will win in the long run than I have that I sit here writing to you, or that this free thought will organize itself into a coherent system. . . . But this organization will be the work of generations

of men, and those who further it most will be those who teach men to rest in no lie and to believe in no verbal delusions. I may be able to help in this direction—perhaps I may have helped already." How much Huxley did help, we of to-day can realize only when we stop to consider that the truths of science which he fought to establish are accepted commonplaces in the thought of to-day, and that the warfare between science and religion has practically ceased.

Huxley the Lecturer

The year 1852 marks the commencement of Huxley's career as a lecturer. He insisted on calling his lectures "People's Lectures." "Popular lectures I hold to be an abomination unto the Lord," he declared. He tells this story about himself at the opening of his lecture work: "In my early period as a lecturer I had very little confidence in my general powers, but one thing I prided myself upon was clearness. I was once talking of the brain before a large mixed audience, and soon began to feel that no one in the room understood me. Finally I saw the thoroughly interested face of a woman auditor, and took consolation in delivering the remainder of the lecture directly to her. At the close, my feeling as to her interest was confirmed when she came up and asked if she might put one question upon a single point which she had not quite understood. 'Certainly,' I replied. 'Now, professor,' she said, 'is the cerebellum inside or outside the skull?'"

Huxley's success as a lecturer was largely the result of hard work. "I used to say of my own lectures," Huxley declares, "that if nobody else learned anything from them, I did; because I always took a great deal of pains

over them." His first course of lectures to working men was given in 1855. Huxley exerted his great powers to the utmost in these lectures, and they were undoubtedly his best efforts. "Clear, deliberate, never hesitant, nor unduly emphatic, never repetitional, always logical," says his colleague, Professor Howes, "his every word told. . . . Great, however, as were his class lectures, his working men's were greater." Other tributes follow:

"As a lecturer, he was simply perfect," declares the literary critic, Frederic Harrison, "clear, incisive, illuminating, admirably adapting his words to the caliber of his audience."

"On the platform Mr. Huxley was a commanding figure," says Mr. Smalley, his American friend. "He had in him the gift of oratory, had he cared to cultivate it. . . . The first glance magnetized his audience. The eyes were those of one accustomed to command, of one having authority and not fearing on occasion to use it. He was masculine in everything—look, gesture, speech. . . . Sparing of gestures, sparing of emphasis, careless of mere rhetorical or oratorical art, he had nevertheless the secret of the highest art of all, whether in oratory or whatever else—he had simplicity. . . . The voice was rather deep, low, but quite audible, at times sonorous, always full. He used the chest notes."

"His lectures," writes Jeffrey Parker, one of Huxley's old students, "were like his writings, luminously clear, without the faintest disposition to descend to the level of his audience; eloquent, but with no trace of the empty rhetoric which so often does duty for that quality; full of a high seriousness, but with no suspicion of pedantry; lightened by an occasional epigram, or flashes of caustic humour, but with none of the small jocularity in which it is such a temptation to a lecturer to indulge."

And Prof. H. Fairfield Osborn, of Columbia College, a pupil of 1876, says:

"Huxley, as a teacher, can never be forgotten by any of his students. He entered the lecture room promptly as the clock was striking nine, rather quickly, and with his head bent forward, 'as if oppressive with its mind.' He usually glanced attention to his class of about ninety, and began speaking before he reached his chair. . . . He had very few charts, but handled chalk with great skill. . . . Occasionally he would light up the monotony of anatomical description by a bit of humour."

Huxley the Educator

In his address *On Science and Art in Relation to Education* Huxley says: "I take it that the whole object of education is, in the first place, to train the faculties of the young in such a manner as to give their possessors the best chance of being happy and useful in their generation: and in the second place, to furnish them with the most important portions of that immense capitalized experience of the human race which we call knowledge of various kinds." And his definition of a liberal education is well known: "That man, I think, has had a liberal education who has been so trained in youth that his body is the ready servant of his will, and does with ease and pleasure all the work that, as a mechanism, it is capable of; whose intellect is a clear, cold, logic engine, with all its parts of equal strength, and in smooth working order; ready, like a steam engine, to be turned to any kind of work, and spin the gossamers as well as forge the anchors of the mind; whose mind is stored with a knowledge of the great and fundamental truths of Nature, and of the laws of her operations . . . who has learned to love all

beauty, whether of Nature or of Art, to hate all vileness, and to respect others as himself."

In an article in the *Contemporary Review*, 1870, Huxley gives the following sketch of what elementary education should include:

1. Physical discipline and drill as part of the regular business of the school.
2. Domestic training.
3. Ethical and religious training.
4. Intellectual training, including not only reading, writing, and arithmetic, but also the elements of physical science, with drawing, modelling, and singing.

He made an eloquent plea for the use of the Bible in the schools, and as a member of the London School Board was largely instrumental in getting the following resolution adopted:

"That in the schools provided by the Board, the Bible shall be read, and there shall be given therefrom such explanations and such instruction in the principles of religion and morality as are suited to the capacity of the children."

His ideas on the subject of the education of women were expressed in 1865 in an essay, *Emancipation—Black and White*, as follows: "The mind of the average girl is less different from that of the average boy, than the mind of one boy is from that of another; so that whatever argument justifies a given education for all boys, justifies its application to girls as well. So far from imposing artificial restriction upon the acquirement of knowledge by women, throw every facility in their way. . . . They will be none the less sweet for a little wisdom; and the golden hair will not curl less gracefully outside the head by reason of there being brains within. . . . Let them, if they so please, become merchants, barristers, politicians. Let

them have a fair field, but let them understand as the necessary correlative, that they are to have no favor. . . . And the result? Women will find their place and it will neither be that in which they have been held, nor that to which some of them aspire."

Huxley was a pioneer in the fields of scientific and technical education in England, and his ideas found root in a fertile soil in America. But he was by no means an advocate of a one-sided education, of the study of science to the exclusion of the so-called culture studies. "An exclusively scientific training will bring about a mental twist as surely as an exclusively literary training," he declared. But he did make a plea, long and earnest, for the recognition of science in the school curriculum. A study of science, and of science alone, Huxley insisted, would show man his relation to the universe. As a member of the committee of the British Association to report on the teaching of science in the public schools, 1868–69, Huxley, in consultation with Tyndall, drew up a scheme, the fundamental principle of which was: "To begin with Observational Science, facts collected; to proceed to Classificatory Science, facts arranged; and to end with Inductive Science, facts reasoned upon and laws deduced." As a member of the London School Board he advocated instruction in the first elements of physical science, "in what is the nature of the common things about him [the child] and in what relation this actual body of man stands to the universe outside of it."

Huxley was an earnest advocate of technical education. However, he believed in a good elementary English education before specialization. His views are summed up in an address given in 1877 before the Working Men's Club and Institute Union. "The workshop is the only real school for a handicraft. The education which pre-

cedes that of the workshop should be entirely devoted to the strengthening of the body, the elevation of the moral faculties, and the cultivation of the intelligence; and, especially, to the imbuing the mind with a broad and clear view of the laws of that natural world with the components of which the handicraftsman will have to deal. . . . He should devote the precious hours of preliminary education to things of the mind, which have no direct and immediate bearing on his branch of industry, though they lie at the foundation of all realities." And again in the same year, in a report to the City Companies of London, he says: "It appears to me that if every person who is engaged in an industry had access to instruction in the scientific principles on which that industry is based; in the mode of applying these principles to practice; in the actual use of the means and appliances employed; in the language of the people who know as much about the matter as we do ourselves; and lastly in the art of keeping accounts, Technical Education would have done all that can be required of it."

Huxley the Scientist

In the Preface to *Discourses Biological and Geological,* dated April, 1894, Huxley says: "It must be admitted that the popularization of science, whether by lecture or by essay, has its drawbacks. Success in this department has its perils for those who succeed." Even such well-informed scholars as Dr. Richard Garnett call Huxley's work that of the man who makes few original contributions to science and thought, but states the discoveries of others better than they could have stated them themselves. And Mr. Irving Wilson Vorhees, in his book *The Teachings of Thomas Henry Huxley,* says: "Huxley was not so

profound and untiring an investigator as Darwin, yet he was quicker perhaps in seeing how far-reaching Darwin's results were, and fully as capable of supporting them by illustrations and arguments. For his interest in the advancement of popular scientific thought, all the world owes him a debt of gratitude, and hence he deserves an enduring place among the sons of light."

Yet Huxley was by no means the *mere* popularizer. The listing of the titles of his original contributions to science fills ten pages in the Appendix to *Life and Letters* by his son; and the testimony that follows seems alone sufficient to make out a case for Huxley, the scientist.

In the Preface to the *Collection of Huxley's Scientific Memoirs,* edited by Sir Michael Foster and Professor E. Ray Lankester, is the following statement: "Apart from the influence exerted by his popular writings, the progress of biology during the present century was largely due to labors of his, of which the general public knew nothing—he was in some respects the most original and most fertile in discovery of all his fellow-workers in the same branch of science."

Professor A. Kowalesky, in an address delivered at the International Congress of Zoölogy in 1895, shortly after Huxley's death, paid him the following tribute: "In the person of Huxley, science has sustained a great loss. We do not know any other investigators of our century who had the talent of foresight to such an extent as Huxley. . . . The two names of Darwin and Huxley have built up the story of the scientific world."[1] And Professor Ernst Haeckel, the great German scientist, declared, "As long as Darwin lives as a reformer in the history of biology,

[1] *Nature,* liii, p. 651, 1895.

so long will Huxley be celebrated as one of his most faithful friends and most successful fellow-workers." [1]

Huxley, the Writer

It fell to Huxley's lot to demonstrate that the scientist must respect the laws of literary expression if he would be heard. On the other hand, "The whole of modern thought is steeped in science," Huxley declared; "it has made its way into the works of our best poets, and even the mere man of letters, who affects to ignore and despise science, is unconsciously impregnated with her spirit, and indebted for his best products to her methods." In a word, "science and literature are not two things, but two sides of one thing." Huxley acquired his literary style through conscious, deliberate effort. He says himself, "The fact is that I have a great love and respect for my native tongue, and take great pains to use it properly. Sometimes I write essays half a dozen times before I can get them into the proper shape." His literary creed was "to say that which has to be said in such language that you can stand cross-examination on each word." A better one it would be hard to find for students of English.

The following tributes to Huxley's literary powers are interesting:

"Spedding, in a letter upon the influence of Bacon on his own style, . . . asserted that, if, as a young man, he had fallen in with Huxley's writings before Bacon's they would have produced the same effect on him." [2]

"Solidly grounded in his patiently acquired facts,

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[1] *Fortnightly Review*, New Series, lviii, p. 469, 1895.

[2] *Life*, i, p. 320.

preaching a profounder reverence for truth than was possible before the advent of modern science, and equipped with no mean literary ability, Huxley entered the arena of nineteenth century thought and carried off some of its proudest laurels." [1]

"He had vigor and that imaginative use of language without which the full value of words is never brought out. . . . The impulse for sincerity, coupled with an instinct for diction and with long practice and unwearied effort, made him the admirable writer he was." [2]

"He was a forceful and epigrammatic writer, and had a command of English second to no scientist England had ever produced. He was the only one of his group that had a distinct literary style." [3]

"In his case, more than that of his contemporaries, it is strictly true that the style is the man. . . . In Professor Huxley's work . . . we never miss his fascinating presence; now he is gravely shaking his head, now compressing the lips with emphasis, and from time to time, with a quiet twinkle of the eye, making unexpected apologies, or protesting that he is of a modest and peace-loving nature. . . . Everything which has entered the author's brain by eye or ear . . . comes out again to us—clarified, sifted, arranged, and vivified by its passage through the logical machine of his strong individuality." [4]

"He deals with form not only as a mechanical engineer *in partibus* (Huxley's own description of himself), but also as an artist, a born lover of form, a character

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[1] Newcomer, A., *English Literature*, p. 367.

[2] Smalley, G., *Scribner's*, October, 1895.

[3] Hubbard, E., *Little Journeys*, September, 1905.

[4] Lankester, Professor Ray (in a *Review of the 9th Vol. Coll. Essays*), *Nature*, Feb. 1, 1894.

which others recognize in him, though he does not himself set it down in his analysis." [1]

"What he writes would be worth reading, for its style and expression alone, were it of no scientific authority." [2]

"He had an admirable style, free alike from the great faults of his contemporaries, 'preciousness' and slipshodness, and a knack of crisp but not too mannered phrase, recalling that of Swift, or still more of Bentley." [3]

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[1] Lankester, Professor Ray, quoted in *Life*, ii, p. 394.

[2] McCarthy, Justin, *Science and Orthodoxy in England:* in *Modern Leaders*, pp. 237, 238.

[3] Saintsbury, George, *A History of Nineteenth Century Literature*, p. 416.

SUGGESTIVE QUESTIONS FOR PUPILS ON THE SEVERAL ESSAYS

Autobiography

STRUCTURAL

1. Show that the selection of facts in this sketch is suited to the character of the essay.
2. What important facts are left out? Why? (See Int., Sketch of Huxley's Life.)
3. What trait of character does Huxley show in this sketch?
4. Commit to memory Huxley's aims in life as given in the *Autobiography*.
5. Compare with this statement the ideal of life as given in his diary. (See Int., Sketch of Huxley's Life.)
6. Compare this sketch with the Spectator's account of his life. (See Spectator No. 1.)

RHETORICAL

1. Give evidences of humor in the account.
2. Find instances of hyperbole in the sketch.
3. Discuss Huxley's use of this figure of speech (hyperbole) from the point of view of rhetorical effect.
4. Explain in detail Huxley's designation of the thought movement of his time as the New Reformation. (See Int., *Huxley's Place in the Intellectual Life of his Times*.)

On the Educational Value of the Natural History Sciences

STRUCTURAL

1. What method of exposition does Huxley use to develop the nature of the biological sciences?
2. Give his famous definition of science.
3. Work out in detail Huxley's refutation of the four objections to the proposition "that the scientific method is the same for the biological science as for all other sciences."
4. What kinds of proof are used in each case?
5. Give Huxley's analysis of the scientific method.
6. What is the purpose of the comparison between mathematics and biology?

RHETORICAL

1. Discuss the summaries and short paragraphs of the essay from the point of view of rhetorical effect.
2. Give instances of humor and irony in the address.
3. This essay is full of homely examples like that of the mountaineer and man of the plains. Cite others.
4. Discuss the rhetorical question in the essay.
5. What is the rhetorical effect of the summary?

On the Advisableness of Improving Natural Knowledge

STRUCTURAL

1. What topics are discussed in the first group of paragraphs? Purpose?
2. What is the point made in the second group?

3. Make a brief developing the first part of the thesis: "I say that natural knowledge, seeking to satisfy natural wants, has found the idea which can alone still spiritual cravings." The second part: "I say that natural knowledge in desiring to ascertain the laws of comfort, has been driven to discover those of conduct, and to lay the foundation of a new morality."
4. What kind of proof does Huxley use in the first case? In the second?
5. State in your own words the conclusion reached in the last paragraph.

RHETORICAL

1. Show how the concreteness of the Introduction drives the point home.
2. How does Huxley gain vividness in the Introduction?
3. How does he gain emphasis in the Introduction?
4. Cite other instances in this essay of his use of this same device for gaining emphasis.
5. Compare, in this respect, Huxley with Macaulay.
6. Give instances of epigrammatic phrasing in the essay.
7. Discuss, from the point of view of effectiveness, the summary in the last paragraph.
8. Find other good summaries in the essay.
9. Make a study of the periodic sentence as used in this essay.
10. Make a study of the words from the point of view of simplicity, vividness, and fitness.

A Liberal Education: And Where to Find It

STRUCTURAL

1. What is the purpose of the Introduction?
2. Outline the essay, following the suggestion implied by its title.

3. Give Huxley's definition of education.
4. What distinction does he make between *natural* and *artificial* education?
5. Give Huxley's definition of a liberal education.
6. Analyze Huxley's indictment of English education, elementary, secondary, and university.
7. How does Huxley apply what he has said to the South London Working Men's College?
8. Show the relation between the opening paragraph and the closing group of paragraphs.

RHETORICAL

1. What use does Huxley make of example in this essay? Cite specific instances.
2. Of what force is the satire in the Introduction? Find other instances of its use in the essay.
3. Analyze carefully the figure of speech in which life is compared to a game of chess. Why is it effective?
4. Make a study of the use of words in this essay.
5. Make a study of the sentences from the point of view of rhetoric.

On a Piece of Chalk

STRUCTURAL

1. What form of discourse is here used?
2. What is the purpose of the Introduction?
3. What is the purpose of studying the *Globigerinæ*?
4. How does Huxley prove that *Globigerina* is the product of vital activity?
5. What kinds of evidence does he here present?
6. Work out a brief developing the proposition "that chalk is the dried mud of an ancient sea."

7. Make a brief developing the proposition "that the chalk sea is very ancient."
8. In the same way analyze Huxley's argument "that the earth, from the time of the chalk to the present day, has been the theater of a series of changes, as vast in their amount as they were slow in their progress."
9. Discuss Huxley's use of evidence in establishing the above propositions.

RHETORICAL

1. What does Huxley gain by the directness of his introductory paragraphs; by starting with the near and going to the remote?
2. Give instances of epigrammatic expressions.
3. There are fine summaries throughout the essay. Find illustrations and show their fitness.
4. What is the force of the parallelism drawn between the chalk makers and the pyramid builders?
5. Make a study of Huxley's topic sentences in this essay; of his transitions; of his summaries.
6. Show how the concluding paragraph rounds out the discussion, making a perfect unit of the whole.

On Science and Art in Relation to Education

STRUCTURAL

1. Make an outline of this essay.
2. Discuss the four points necessary to be attended to for the successful teaching of science.
3. What are the principal subjects of education according to Huxley?
4. Defend his choice.
5. Into what two groups does Huxley classify the subjects of all knowledge?

RHETORICAL

1. Make a study of Huxley's transitions in this essay.
2. Compare the paragraphs in this essay with those in the essay *On the Educational Value of the Natural History Sciences,* from the point of view of length.
3. What is the reason for the difference?
4. Are the words in this essay more or less specific than those in the essay on *A Lobster: or the Study of Zoölogy?*
5. Account for the difference.

A Lobster: or the Study of Zoölogy

STRUCTURAL

1. How does Huxley adapt the subject-matter of this essay to his audience?
2. State the theme of the essay.
3. What is the purpose of the lecture?
4. What use is made of his illustration, the lobster?

RHETORICAL

1. Make a study of Huxley's directness of style as illustrated by this essay.
2. Make a study of his sentences as here illustrated.
3. Comment on his use of words as to fitness and suggestiveness.

On the Study of Biology

STRUCTURAL

1. State Huxley's plan as given at the opening of the essay.

2. Analyze in detail his development of each point.
3. State in complete sentences the theme of the essay and the method of developing the theme.

RHETORICAL

1. Make a study of Huxley's allusions in this essay.
2. What devices does Huxley use in this essay for gaining emphasis?
3. Compare the method of treatment of this subject with that of *A Lobster: or the Study of Zoölogy.*

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SELECTED ESSAYS OF HUXLEY

I

AUTOBIOGRAPHY

[The *Autobiography* was written in 1889, and was published by C. Engel as one of a series of biographical sketches. It was also prefixed to the first volume of Huxley's *Collected Essays,* published in 1890.

Huxley writes to his wife, March 2, 1889: "A man who is bringing out a series of portraits of celebrities, with a sketch of their career attached, has bothered me out of my life for something to go with my portrait, and to escape the abominable bad taste of some of the notices, I have done that. I shall show it you before it goes back to Engel in proof."

Because of its grace of style, it is suggested that this sketch be read aloud. John Fiske, a close friend of Huxley's, said that Huxley was nothing if not playful. Evidences of this playful turn are numerous throughout the *Autobiography.* It flows along with the ease of a Spectator Paper, enlivened by an occasional sparkle of humor. A comparative reading of Addison's Spectator Paper No. 1, March 1, 1711, in which the Spectator gives an account of himself, is suggested.

It may be well to study the selection of facts Huxley makes, in the light of the purpose for which the *Autobiography* was written. An interesting comparison may be made between Huxley's statement of his aims in life (p. 13) and his ideal of life as given in his diary (Int., p. xiv). A study of the figures of speech in this sketch may be worth while,

especially of Huxley's designation of the thought movement of his time as the New Reformation.]

> And when I consider, in one view, the many things . . . which I have upon my hands, I feel the burlesque of being employed in this manner at my time of life. But, in another view, and taking in all circumstances, these things, as trifling as they may appear, no less than things of greater importance, seem to be put upon me to do. . . .—*Bishop Butler to the Duchess of Somerset.*

THE "many things" to which the Duchess's correspondent here refers are the repairs and improvements of the episcopal seat at Auckland. I doubt if the great apologist, greater in nothing than in the simple dignity of his character, would have considered the writing an account of himself as a thing which could be put upon him to do whatever circumstances might be taken in. But the good bishop lived in an age when a man might write books and yet be permitted to keep his private existence to himself; in the pre-Boswellian epoch, when the germ of the photographer lay in the womb of the distant future, and the interviewer who pervades our age was an unforeseen, indeed unimaginable, birth of time.

At present, the most convinced believer in the aphorism "Bene qui latuit, bene vixit," is not always able to act up to it. An importunate person informs him that his portrait is about to be published and will be accompanied by a biography which the importunate person proposes to write. The sufferer knows what that means; either he undertakes to revise the "biography" or he does not. In the former case, he makes himself responsible; in the latter, he allows the publication of a mass of more or less fulsome inaccuracies for which he will be held responsible by those who are familiar with the prevalent art of self-advertisement. On the whole, it may be better to get

over the "burlesque of being employed in this manner" and do the thing himself.

It was by reflections of this kind that, some years ago, I was led to write and permit the publication of the subjoined sketch.

I was born about eight o'clock in the morning on the 4th of May, 1825, at Ealing, which was, at that time, as quiet a little country village as could be found within half-a-dozen miles of Hyde Park Corner. Now it is a suburb of London with, I believe, 30,000 inhabitants. My father was one of the masters in a large semi-public school which at one time had a high reputation. I am not aware that any portents preceded my arrival in this world, but, in my childhood, I remember hearing a traditional account of the manner in which I lost the chance of an endowment of great practical value. The windows of my mother's room were open, in consequence of the unusual warmth of the weather. For the same reason, probably, a neighboring beehive had swarmed, and the new colony, pitching on the window-sill, was making its way into the room when the horrified nurse shut down the sash. If that well-meaning woman had only abstained from her ill-timed interference, the swarm might have settled on my lips, and I should have been endowed with that mellifluous eloquence which, in this country, leads far more surely than worth, capacity, or honest work, to the highest places in Church and State. But the opportunity was lost, and I have been obliged to content myself through life with saying what I mean in the plainest of plain language, than which, I suppose, there is no habit more ruinous to a man's prospects of advancement.

Why I was christened Thomas Henry I do not know; but it is a curious chance that my parents should have

fixed for my usual denomination upon the name of that particular Apostle with whom I have always felt most sympathy. Physically and mentally I am the son of my mother so completely—even down to peculiar movements of the hands, which made their appearance in me as I reached the age she had when I noticed them—that I can hardly find any trace of my father in myself, except an inborn faculty for drawing, which unfortunately, in my case, has never been cultivated, a hot temper, and that amount of tenacity of purpose which unfriendly observers sometimes call obstinacy.

My mother was a slender brunette, of an emotional and energetic temperament, and possessed of the most piercing black eyes I ever saw in a woman's head. With no more education than other women of the middle classes in her day, she had an excellent mental capacity. Her most distinguishing characteristic, however, was rapidity of thought. If one ventured to suggest she had not taken much time to arrive at any conclusion, she would say, "I cannot help it, things flash across me." That peculiarity has been passed on to me in full strength; it has often stood me in good stead; it has sometimes played me sad tricks, and it has always been a danger. But, after all, if my time were to come over again, there is nothing I would less willingly part with than my inheritance of mother wit.

I have next to nothing to say about my childhood. In later years my mother, looking at me almost reproachfully, would sometimes say, "Ah! you were such a pretty boy!" whence I had no difficulty in concluding that I had not fulfilled my early promise in the matter of looks. In fact, I have a distinct recollection of certain curls of which I was vain, and of a conviction that I closely resembled that handsome, courtly gentleman, Sir

Herbert Oakley, who was vicar of our parish, and who was as a god to us country folk, because he was occasionally visited by the then Prince George of Cambridge. I remember turning my pinafore wrong side forwards in order to represent a surplice, and preaching to my mother's maids in the kitchen as nearly as possible in Sir Herbert's manner one Sunday morning when the rest of the family were at church. That is the earliest indication I can call to mind of the strong clerical affinities which my friend Mr. Herbert Spencer has always ascribed to me, though I fancy they have for the most part remained in a latent state.

My regular school training was of the briefest, perhaps fortunately, for though my way of life has made me acquainted with all sorts and conditions of men, from the highest to the lowest, I deliberately affirm that the society I fell into at school was the worst I have ever known. We boys were average lads, with much the same inherent capacity for good and evil as any others; but the people who were set over us cared about as much for our intellectual and moral welfare as if they were baby-farmers. We were left to the operation of the struggle for existence among ourselves, and bullying was the least of the ill practices current among us. Almost the only cheerful reminiscence in connection with the place which arises in my mind is that of a battle I had with one of my class-mates, who had bullied me until I could stand it no longer. I was a very slight lad, but there was a wild-cat element in me which, when roused, made up for lack of weight, and I licked my adversary effectually. However, one of my first experiences of the extremely rough-and-ready nature of justice, as exhibited by the course of things in general, arose out of the fact that I—the victor—had a black eye, while he—the vanquished—had none, so that I got into disgrace and he did not. We made it

up, and thereafter I was unmolested. One of the greatest shocks I ever received in my life was to be told a dozen years afterwards by the groom who brought me my horse in a stable-yard in Sydney that he was my quondam antagonist. He had a long story of family misfortune to account for his position, but at that time it was necessary to deal very cautiously with mysterious strangers in New South Wales, and on inquiry I found that the unfortunate young man had not only been "sent out," but had undergone more than one colonial conviction.

As I grew older, my great desire was to be a mechanical engineer, but the fates were against this and, while very young, I commenced the study of medicine under a medical brother-in-law. But, though the Institute of Mechanical Engineers would certainly not own me, I am not sure that I have not all along been a sort of mechanical engineer *in partibus infidelium*. I am now occasionally horrified to think how very little I ever knew or cared about medicine as the art of healing. The only part of my professional course which really and deeply interested me was physiology, which is the mechanical engineering of living machines; and, notwithstanding that natural science has been my proper business, I am afraid there is very little of the genuine naturalist in me. I never collected anything, and species work was always a burden to me; what I cared for was the architectural and engineering part of the business, the working out the wonderful unity of plan in the thousands and thousands of diverse living constructions, and the modifications of similar apparatuses to serve diverse ends. The extraordinary attraction I felt towards the study of the intricacies of living structure nearly proved fatal to me at the outset. I was a mere boy—I think between thirteen and fourteen years of age—when I was taken by some older student

friends of mine to the first *post-mortem* examination I ever attended. All my life I have been most unfortunately sensitive to the disagreeables which attend anatomical pursuits, but on this occasion my curiosity overpowered all other feelings, and I spent two or three hours in gratifying it. I did not cut myself, and none of the ordinary symptoms of dissection-poison supervened, but poisoned I was somehow, and I remember sinking into a strange state of apathy. By way of a last chance, I was sent to the care of some good, kind people, friends of my father's, who lived in a farmhouse in the heart of Warwickshire. I remember staggering from my bed to the window on the bright spring morning after my arrival, and throwing open the casement. Life seemed to come back on the wings of the breeze, and to this day the faint odour of wood-smoke, like that which floated across the farm-yard in the early morning, is as good to me as the "sweet south upon a bed of violets." I soon recovered, but for years I suffered from occasional paroxysms of internal pain, and from that time my constant friend, hypochondriacal dyspepsia, commenced his half century of cotenancy of my fleshly tabernacle.

Looking back on my "Lehrjahre," I am sorry to say that I do not think that any account of my doings as a student would tend to edification. In fact, I should distinctly warn ingenuous youth to avoid imitating my example. I worked extremely hard when it pleased me, and when it did not—which was a very frequent case—I was extremely idle (unless making caricatures of one's pastors and masters is to be called a branch of industry), or else wasted my energies in wrong directions. I read everything I could lay hands upon, including novels, and took up all sorts of pursuits to drop them again quite as speedily. No doubt it was very largely my own fault, but

the only instruction from which I ever obtained the proper effect of education was that which I received from Mr. Wharton Jones, who was the lecturer on physiology at the Charing Cross School of Medicine. The extent and precision of his knowledge impressed me greatly, and the severe exactness of his method of lecturing was quite to my taste. I do not know that I have ever felt so much respect for anybody as a teacher before or since. I worked hard to obtain his approbation, and he was extremely kind and helpful to the youngster who, I am afraid, took up more of his time than he had any right to do. It was he who suggested the publication of my first scientific paper —a very little one—in the *Medical Gazette* of 1845, and most kindly corrected the literary faults which abounded in it, short as it was; for at that time, and for many years afterwards, I detested the trouble of writing, and would take no pains over it.

It was in the early spring of 1846, that, having finished my obligatory medical studies and passed the first M.B. examination at the London University—though I was still too young to qualify at the College of Surgeons—I was talking to a fellow-student (the present eminent physician, Sir Joseph Fayrer), and wondering what I should do to meet the imperative necessity for earning my own bread, when my friend suggested that I should write to Sir William Burnett, at that time Director-General for the Medical Service of the Navy, for an appointment. I thought this rather a strong thing to do, as Sir William was personally unknown to me, but my cheery friend would not listen to my scruples, so I went to my lodgings and wrote the best letter I could devise. A few days afterwards I received the usual official circular of acknowledgment, but at the bottom there was written an instruction to call at Somerset House on such a day.

I thought that looked like business, so at the appointed time I called and sent in my card, while I waited in Sir William's ante-room. He was a tall, shrewd-looking old gentleman, with a broad Scotch accent—and I think I see him now as he entered with my card in his hand. The first thing he did was to return it, with the frugal reminder that I should probably find it useful on some other occasion. The second was to ask whether I was an Irishman. I suppose the air of modesty about my appeal must have struck him. I satisfied the Director-General that I was English to the backbone, and he made some inquiries as to my student career, finally desiring me to hold myself ready for examination. Having passed this, I was in Her Majesty's Service, and entered on the books of Nelson's old ship, the *Victory*, for duty at Haslar Hospital, about a couple of months after I made my application.

My official chief at Haslar was a very remarkable person, the late Sir John Richardson, an excellent naturalist, and far-famed as an indomitable Arctic traveller. He was a silent, reserved man, outside the circle of his family and intimates; and, having a full share of youthful vanity, I was extremely disgusted to find that "Old John," as we irreverent youngsters called him, took not the slightest notice of my worshipful self either the first time I attended him, as it was my duty to do, or for some weeks afterwards. I am afraid to think of the lengths to which my tongue may have run on the subject of the churlishness of the chief, who was, in truth, one of the kindest-hearted and most considerate of men. But one day, as I was crossing the hospital square, Sir John stopped me, and heaped coals of fire on my head by telling me that he had tried to get me one of the resident appointments, much coveted by the assistant surgeons, but that the Admiralty

had put in another man. "However," said he, "I mean to keep you here till I can get you something you will like," and turned upon his heel without waiting for the thanks I stammered out. That explained how it was I had not been packed off to the West Coast of Africa like some of my juniors, and why, eventually, I remained altogether seven months at Haslar.

After a long interval, during which "Old John" ignored my existence almost as completely as before, he stopped me again as we met in a casual way, and describing the service on which the *Rattlesnake* was likely to be employed, said that Captain Owen Stanley, who was to command the ship, had asked him to recommend an assistant surgeon who knew something of science; would I like that? Of course I jumped at the offer. "Very well, I give you leave; go to London at once and see Captain Stanley." I went, saw my future commander, who was very civil to me, and promised to ask that I should be appointed to his ship, as in due time I was. It is a singular thing that, during the few months of my stay at Haslar, I had among my messmates two future Directors-General of the Medical Service of the Navy (Sir Alexander Armstrong and Sir John Watt-Reid), with the present President of the College of Physicians and my kindest of doctors, Sir Andrew Clark.

Life on board Her Majesty's ships in those days was a very different affair from what it is now, and ours was exceptionally rough, as we were often many months without receiving letters or seeing any civilised people but ourselves. In exchange, we had the interest of being about the last voyagers, I suppose, to whom it could be possible to meet with people who knew nothing of fire-arms—as we did on the south Coast of New Guinea—and of making acquaintance with a variety of interesting

savage and semi-civilised people. But, apart from experience of this kind and the opportunities offered for scientific work, to me, personally, the cruise was extremely valuable. It was good for me to live under sharp discipline; to be down on the realities of existence by living on bare necessaries; to find out how extremely well worth living life seemed to be when one woke up from a night's rest on a soft plank, with the sky for canopy and cocoa and weevilly biscuit the sole prospect for breakfast; and, more especially, to learn to work for the sake of what I got for myself out of it, even if it all went to the bottom and I along with it. My brother officers were as good fellows as sailors ought to be and generally are, but, naturally, they neither knew nor cared anything about my pursuits, nor understood why I should be so zealous in pursuit of the objects which my friends, the middies, christened "Buffons," after the title conspicuous on a volume of the "Suites à Buffon," which stood on my shelf in the chart room.

During the four years of our absence, I sent home communication after communication to the "Linnean Society," with the same result as that obtained by Noah when he sent the raven out of his ark. Tired at last of hearing nothing about them, I determined to do or die, and in 1849 I drew up a more elaborate paper and forwarded it to the Royal Society. This was my dove, if I had only known it. But owing to the movements of the ship, I heard nothing of that either until my return to England in the latter end of the year 1850, when I found that it was printed and published, and that a huge packet of separate copies awaited me. When I hear some of my young friends complain of want of sympathy and encouragement, I am inclined to think that my naval life was not the least valuable part of my education.

Three years after my return were occupied by a battle between my scientific friends on the one hand and the Admiralty on the other, as to whether the latter ought, or ought not, to act up to the spirit of a pledge they had given to encourage officers who had done scientific work by contributing to the expense of publishing mine. At last the Admiralty, getting tired, I suppose, cut short the discussion by ordering me to join a ship, which thing I declined to do, and as Rastignac, in the Père Goriot, says to Paris, I said to London "*à nous deux.*" I desired to obtain a Professorship of either Physiology or Comparative Anatomy, and as vacancies occurred I applied, but in vain. My friend, Professor Tyndall, and I were candidates at the same time, he for the Chair of Physics and I for that of Natural History in the University of Toronto, which, fortunately, as it turned out, would not look at either of us. I say fortunately, not from any lack of respect for Toronto, but because I soon made up my mind that London was the place for me, and hence I have steadily declined the inducements to leave it, which have at various times been offered. At last, in 1854, on the translation of my warm friend Edward Forbes, to Edinburgh, Sir Henry de la Beche, the Director-General of the Geological Survey, offered me the post Forbes vacated of Paleontologist and Lecturer on Natural History. I refused the former point blank, and accepted the latter only provisionally, telling Sir Henry that I did not care for fossils, and that I should give up Natural History as soon as I could get a physiological post. But I held the office for thirty-one years, and a large part of my work has been paleontological.

At that time I disliked public speaking, and had a firm conviction that I should break down every time I opened my mouth. I believe I had every fault a speaker could

have (except talking at random or indulging in rhetoric), when I spoke to the first important audience I ever addressed, on a Friday evening at the Royal Institution, in 1852. Yet, I must confess to having been guilty, *malgré moi,* of as much public speaking as most of my contemporaries, and for the last ten years it ceased to be so much of a bugbear to me. I used to pity myself for having to go through this training, but I am now more disposed to compassionate the unfortunate audiences, especially my ever-friendly hearers at the Royal Institution, who were the subjects of my oratorical experiments.

The last thing that it would be proper for me to do would be to speak of the work of my life, or to say at the end of the day whether I think I have earned my wages or not. Men are said to be partial judges of themselves. Young men may be, I doubt if old men are. Life seems terribly foreshortened as they look back, and the mountain they set themselves to climb in youth turns out to be a mere spur of immeasurably higher ranges when, with failing breath, they reach the top. But if I may speak of the objects I have had more or less definitely in view since I began the ascent of my hillock, they are briefly these: To promote the increase of natural knowledge and to forward the application of scientific methods of investigation to all the problems of life to the best of my ability, in the conviction which has grown with my growth and strengthened with my strength, that there is no alleviation for the sufferings of mankind except veracity of thought and of action, and the resolute facing of the world as it is when the garment of make-believe by which pious hands have hidden its uglier features is stripped off.

It is with this intent that I have subordinated any reasonable, or unreasonable, ambition for scientific fame which I may have permitted myself to entertain to other

ends; to the popularisation of science; to the development and organisation of scientific education; to the endless series of battles and skirmishes over evolution; and to untiring opposition to that ecclesiastical spirit, that clericalism, which in England, as everywhere else, and to whatever denomination it may belong, is the deadly enemy of science.

In striving for the attainment of these objects, I have been but one among many, and I shall be well content to be remembered, or even not remembered, as such. Circumstances, among which I am proud to reckon the devoted kindness of many friends, have led to my occupation of various prominent positions, among which the Presidency of the Royal Society is the highest. It would be mock modesty on my part, with these and other scientific honours which have been bestowed upon me, to pretend that I have not succeeded in the career which I have followed, rather because I was driven into it than of my own free will; but I am afraid I should not count even these things as marks of success if I could not hope that I had somewhat helped that movement of opinion which has been called the New Reformation.

II

ON THE EDUCATIONAL VALUE OF THE NATURAL HISTORY SCIENCES

[1854]

[A lecture, delivered at St. Martin's Hall, July 22, 1854. It marks the beginning of one important side of Huxley's life work, his endeavor to secure a fitting place for science in education. In his Preface to the volume of *Collected Essays* in which this is included, dated September 4, 1893, Huxley says: "The oldest piece, that *On the Educational Value of the Natural History Sciences,* contains some crudities, which I repudiated when the lecture was first reprinted, more than twenty years ago; but it will be seen that much of what I have had to say later on in life is merely a development of the propositions enumerated in this early and sadly imperfect piece of work." Nevertheless, it contains a "luminous exposition of the scientific method" and many fine passages which alone make it worth the student's while.

In point of view of composition, this essay is, perhaps, less compact than any of the others in this collection. However, while less polished and less closely knit than the others, it exhibits no less certainty of touch. Indeed, when we consider the popular audience to whom it was addressed, we cannot but feel that vigor and snap, so necessary on such an occasion, are gained by its short, terse sentences, its clean-cut, if rather abrupt, divisions of thought. In it we have fine examples of exposition by means of definition and illustration, and of argument both direct and indirect.

The student should make a careful analysis of Huxley's plan of treatment; of his discussion of the nature of the biological sciences, especially of his use of illustration in this connection; of his exposition of the scientific method; of his famous definition of science.

There is good opportunity in this essay for practice in argumentation. For instance, an excellent exercise is to work out, in the form of a brief, Huxley's refutation of the four objections to the proposition that "the scientific method is the same for biological science as for all other sciences.

Another interesting argument could be developed through the discussion of the value of the study of Biology as a means of mental discipline.

Interesting studies may also be made of the summaries and short paragraphs of the essay, from the point of view of rhetorical effect; of Huxley's use of humor and irony in the address; and of his choice of homely examples like that on page 31, line 15, (the mountaineer and the man of the plains) for making his point.]

THE subject to which I have to beg your attention during the ensuing hour is "The Relation of Physiological Science to other Branches of Knowledge."

Had circumstances permitted of the delivery, in their strict logical order, of that series of discourses of which the present lecture is a member, I should have preceded my friend and colleague Mr. Henfrey, who addressed you on Monday last; but while, for the sake of that order, I must beg you to suppose that this discussion of the educational bearings of Biology in general *does* precede that of Special Zoölogy and Botany, I am rejoiced to be able to take advantage of the light thus already thrown upon the tendency and methods of Physiological Science.

Regarding Physiological Science, then, in its widest sense—as the equivalent of *Biology*—the Science of Individual Life—we have to consider in succession:

1. Its position and scope as a branch of knowledge.
2. Its value as a means of mental discipline.
3. Its worth as practical information.

And lastly,

4. At what period it may best be made a branch of education.

Our conclusions on the first of these heads must depend, of course, upon the nature of the subject-matter of Biology; and I think a few preliminary considerations will place before you in a clear light the vast difference which exists between the living bodies with which Physiological science is concerned, and the remainder of the universe—between the phænomena of Number and Space, of Physical and of Chemical force, on the one hand, and those of Life on the other.

The mathematician, the physicist, and the chemist contemplate things in a condition of rest; they look upon a state of equilibrium as that to which all bodies normally tend.

The mathematician does not suppose that a quantity will alter, or that a given point in space will change its direction with regard to another point, spontaneously. And it is the same with the physicist. When Newton saw the apple fall, he concluded at once that the act of falling was not the result of any power inherent in the apple, but that it was the result of the action of something else on the apple. In a similar manner, all physical force is regarded as the disturbance of an equilibrium to which things tended before its exertion—to which they will tend again after its cessation.

The chemist equally regards chemical change in a body as the effect of the action of something external to the body changed. A chemical compound once formed would

persist forever, if no alteration took place in surrounding conditions.

But to the student of Life the aspect of Nature is reversed. Here, incessant, and, so far as we know, spontaneous change is the rule, rest the exception—the anomaly to be accounted for. Living things have no inertia, and tend to no equilibrium.

Permit me, however, to give more force and clearness to these somewhat abstract considerations by an illustration or two.

Imagine a vessel full of water, at the ordinary temperature, in an atmosphere saturated with vapor. The *quantity* and the *figure* of that water will not change, so far as we know, forever.

Suppose a lump of gold be thrown into the vessel—motion and disturbance of figure exactly proportional to the momentum of the gold will take place. But after a time the effects of this disturbance will subside—equilibrium will be restored, and the water will return to its passive state.

Expose the water to cold—it will solidify—and in so doing its particles will arrange themselves in definite crystalline shapes. But once formed, these crystals change no further.

Again, substitute for the lump of gold some substance capable of entering into chemical relations with the water: —say, a mass of that substance which is called "protein" —the substance of flesh:—a very considerable disturbance of equilibrium will take place—all sorts of chemical compositions and decompositions will occur; but in the end, as before, the result will be the resumption of a condition of rest.

Instead of such a mass of *dead* protein, however, take a particle of *living* protein—one of those minute micro-

scopic living things which throng our pools, and are known as Infusoria—such a creature, for instance, as an Euglena, and place it in our vessel of water. It is a round mass provided with a long filament, and except in this peculiarity of shape, presents no appreciable physical or chemical difference whereby it might be distinguished from the particle of dead protein.

But the difference in the phænomena to which it will give rise is immense: in the first place it will develop a vast quantity of physical force—cleaving the water in all directions with considerable rapidity by means of the vibrations of the long filament of cilium.

Nor is the amount of chemical energy which the little creature possesses less striking. It is a perfect laboratory in itself, and it will act and react upon the water and the matters contained therein; converting them into new compounds resembling its own substance, and at the same time giving up portions of its own substance which have become effete.

Furthermore, the Euglena will increase in size; but this increase is by no means unlimited, as the increase of a crystal might be. After it has grown to a certain extent it divides, and each portion assumes the form of the original, and proceeds to repeat the process of growth and division.

Nor is this all. For after a series of such divisions and subdivisions, these minute points assume a totally new form, lose their long tails—round themselves, and secrete a sort of envelope or box, in which they remain shut up for a time, eventually to resume, directly or indirectly, their primitive mode of existence.

Now, so far as we know, there is no natural limit to the existence of the Euglena, or of any other living germ. A living species once launched into existence tends to live forever.

Consider how widely different this living particle is from the dead atoms with which the physicist and chemist have to do!

The particle of gold falls to the bottom and rests—the particle of dead protein decomposes and disappears—it also rests: but the *living* protein mass neither tends to exhaustion of its forces nor to any permanency of form, but is essentially distinguished as a disturber of equilibrium so far as force is concerned—as undergoing continual metamorphosis and change, in point of form.

Tendency to equilibrium of force and to permanency of form, then, are the characters of that portion of the universe which does not live—the domain of the chemist and physicist.

Tendency to disturb existing equilibrium—to take on forms which succeed one another in definite cycles—is the character of the living world.

What is the cause of this wonderful difference between the dead particle and the living particle of matter appearing in other respects identical? that difference to which we give the name of Life?

I, for one, cannot tell you. It may be that, by and by, philosophers will discover some higher laws of which the facts of life are particular cases—very possibly they will find out some bond between physico-chemical phænomena on the one hand, and vital phænomena on the other. At present, however, we assuredly know of none; and I think we shall exercise a wise humility in confessing that, for us at least, this successive assumption of different states—(external conditions remaining the same)—this *spontaneity of action*—if I may use the term which implies more than I would be answerable for—which constitutes so vast and plain a practical distinction between living bodies and those which do not live, is an ultimate fact; indicating as

such, the existence of a broad line of demarcation between the subject-matter of Biological and that of all other sciences.

For I would have it understood that this simple Euglena is the type of *all* living things, so far as the distinction between these and inert matter is concerned. That cycle of changes, which is constituted by perhaps not more than two or three steps in the Euglena, is as clearly manifested in the multitudinous stages through which the germ of an oak or of a man passes. Whatever forms the Living Being may take on, whether simple or complex, *production, growth, reproduction,* are the phænomena which distinguish it from that which does not live.

If this be true, it is clear that the student, in passing from the physico-chemical to the physiological sciences, enters upon a totally new order of facts; and it will next be for us to consider how far these new facts involve *new* methods, or require a modification of those with which he is already acquainted. Now a great deal is said about the peculiarity of the scientific method in general, and of the different methods which are pursued in the different sciences. The Mathematics are said to have one special method; Physics another, Biology a third, and so forth. For my own part, I must confess that I do not understand this phraseology.

So far as I can arrive at any clear comprehension of the matter, Science is not, as many would seem to suppose, a modification of the black art, suited to the tastes of the nineteenth century, and flourishing mainly in consequence of the decay of the Inquisition.

Science is, I believe, nothing but *trained and organised common sense,* differing from the latter only as a veteran may differ from a raw recruit: and its methods differ from those of common sense only so far as the guards-

man's cut and thrust differ from the manner in which a savage wields his club. The primary power is the same in each case, and perhaps the untutored savage has the more brawny arm of the two. The *real* advantage lies in the point and polish of the swordsman's weapon; in the trained eye quick to spy out the weakness of the adversary; in the ready hand prompt to follow it on the instant. But, after all, the sword exercise is only the hewing and poking of the clubman developed and perfected.

So, the vast results obtained by Science are won by no mystical faculties, by no mental processes, other than those which are practiced by every one of us, in the humblest and meanest affairs of life. A detective policeman discovers a burglar from the marks made by his shoe, by a mental process identical with that by which Cuvier restored the extinct animals of Montmartre from fragments of their bones. Nor does that process of induction and deduction by which a lady, finding a stain of a peculiar kind upon her dress, concludes that somebody has upset the inkstand thereon, differ in any way, in kind, from that by which Adams and Leverrier discovered a new planet.

The man of science, in fact, simply uses with scrupulous exactness the methods which we all, habitually and at every moment, use carelessly; and the man of business must as much avail himself of the scientific method—must be as truly a man of science—as the veriest bookworm of us all; though I have no doubt that the man of business will find himself out to be a philosopher with as much surprise as M. Jourdain exhibited when he discovered that he had been all his life talking prose. If, however, there be no real difference between the methods of science and those of common life, it would seem, on the face of the matter, highly improbable that there should be any difference between the methods of the different sciences; never-

theless, it is constantly taken for granted that there is a very wide difference between the Physiological and other sciences in point of method.

In the first place it is said—and I take this point first, because the imputation is too frequently admitted by Physiologists themselves—that Biology differs from the Physico-chemical and Mathematical sciences in being "inexact."

Now, this phrase "inexact" must refer either to the *methods* or to the *results* of Physiological science.

It cannot be correct to apply it to the methods; for, as I hope to show you by and by, these are identical in all sciences, and whatever is true of Physiological method is true of Physical and Mathematical method.

Is it then the *results* of Biological science which are "inexact"? I think not. If I say that respiration is performed by the lungs; that digestion is effected in the stomach; that the eye is the organ of sight; that the jaws of a vertebrated animal never open sideways, but always up and down; while those of an annulose animal always open sideways, and never up and down—I am enumerating propositions which are as exact as anything in Euclid. How then has this notion of the inexactness of Biological science come about? I believe from two causes: first, because in consequence of the great complexity of the science and the multitude of interfering conditions, we are very often only enabled to predict approximately what will occur under given circumstances; and secondly, because, on account of the comparative youth of the Physiological sciences, a great many of their laws are still imperfectly worked out. But, in an educational point of view, it is most important to distinguish between the essence of a science and the accidents which surround it; and essentially, the methods and results of Physiology are as exact as those of Physics or Mathematics.

It is said that the Physiological method is especially *comparative;* [1] and this dictum also finds favor in the eyes of many. I should be sorry to suggest that the speculators on scientific classification have been misled by the accident of the name of one leading branch of Biology—*Comparative Anatomy;* but I would ask whether *comparison*, and that classification which is the result of comparison, are not the essence of every science whatsoever? How is it possible to discover a relation of cause and effect of *any* kind without comparing a series of cases together in which the supposed cause and effect occur singly, or combined? So far from comparison being in any way peculiar to Biological science, it is, I think, the essence of every science.

A speculative philosopher again tells us that the Biological sciences are distinguished by being sciences of observation and not of experiment! [2]

Of all the strange assertions into which speculation without practical acquaintance with a subject may lead

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[1] "In the third place, we have to review the method of Comparison, which is so specially adapted to the study of living bodies, and by which, above all others, that study must be advanced. In Astronomy, this method is necessarily inapplicable; and it is not till we arrive at Chemistry that this third means of investigation can be used; and then only in subordination to the two others. It is in the study, both statical and dynamical, of living bodies that it first acquires its full development; and its use elsewhere can be only through its application here."—COMTE'S *Positive Philosophy*, translated by Miss Martineau, vol. i, p. 372.

By what method does M. Comte suppose that the equality or inequality of forces and quantities and the dissimilarity or similarity of forms—points of some slight importance not only in Astronomy and Physics, but even in Mathematics—are ascertained, if not by Comparison?

[2] "Proceeding to the second class of means.—Experiment cannot but be less and less decisive, in proportion to the complexity

even an able man, I think this is the very strangest. Physiology not an experimental science? Why, there is not a function of a single organ in the body which has not been determined wholly and solely by experiment! How did Harvey determine the nature of the circulation, except by experiment? How did Sir Charles Bell determine the functions of the roots of the spinal nerve, save by experiment? How do we know the use of a nerve at all, except by experiment? Nay, how do we know even that your eye is your seeing apparatus, unless you make the experiment of shutting it, or that your ear is your hearing apparatus, unless you close it up and thereby discover that you become deaf?

It would really be much more true to say that Physiology is *the* experimental science *par excellence* of all sciences; that in which there is least to be learnt by mere observation, and that which affords the greatest field for the exercise of those faculties which characterise the experimental philosopher. I confess, if any one were to ask me for a model application of the logic of experiment, I should know no better work to put into his hands than Bernard's late Researches on the Functions of the Liver.[1]

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of the phænomena to be explored; and therefore we saw this resource to be less effectual in chemistry than in physics: and we now find that it is eminently useful in chemistry in comparison with physiology. *In fact, the nature of the phænomena seems to offer almost insurmountable impediments to any extensive and prolific application of such a procedure in biology.*"—COMTE, vol. i, p. 367.

M. Comte, as his manner is, contradicts himself two pages further on, but that will hardly relieve him from the responsibility of such a paragraph as the above.

[1] *Nouvelle Fonction du Foie considéré comme organe producteur de matière sucrée chez l'Homme et les Animaux*, par M. Claude Bernard.

Not to give this lecture a too controversial tone, however, I must only advert to one more doctrine, held by a thinker of our own age and country, whose opinions are worthy of all respect. It is, that the Biological sciences differ from all others, inasmuch as in *them* classification takes place by type and not by definition.[1]

It is said, in short, that a natural-history class is not capable of being defined—that the class Rosaceæ, for instance, or the class of Fishes, is not accurately and absolutely definable, inasmuch as its members will present exceptions to every possible definition and that the members of the class are united together only by the circumstance that they are all more like some imaginary average rose or average fish, than they resemble anything else.

But here, as before, I think the distinction has arisen entirely from confusing a transitory imperfection with an essential character. So long as our information concerning them is imperfect, we class all objects together according to resemblances which we *feel,* but cannot *define;* we group them round *types,* in short. Thus if you ask an ordinary person what kinds of animals there are, he will probably say, beasts, birds, reptiles, fishes, insects, etc.

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[1] "*Natural Groups given by Type, not by Definition.* . . . The class is steadily fixed, though not precisely limited; it is given, though not circumscribed; it is determined, not by a boundary-line without, but by a central point within; not by what it strictly excludes, but what it eminently includes; by an example, not by a precept; in short, instead of Definition we have a *Type* for our director. A type is an example of any class, for instance, a species of a genus, which is considered as eminently possessing the characters of the class. All the species which have a greater affinity with this type-species than with any others, form the genus, and are ranged about it, deviating from it in various directions and different degrees."—WHEWELL, *The Philosophy of the Inductive Sciences,* vol. i, pp. 476, 477.

Ask him to define a beast from a reptile, and he cannot do it; but he says, things like a cow or a horse are beasts, and things like a frog or a lizard are reptiles. You see *he does* class by type, and not by definition. But how does this classification differ from that of a scientific Zoöl- ogist? How does the meaning of the scientific class-name of "Mammalia" differ from the unscientific of "Beasts"?

Why, exactly because the former depends on a definition, the latter on a type. The class Mammalia is scientifically defined as "all animals which have a vertebrated skeleton and suckle their young." Here is no reference to type, but a definition rigorous enough for a geometrician. And such is the character which every scientific naturalist recognises as that to which his classes must aspire—knowing, as he does, that classification by type is simply an acknowledgment of ignorance and a temporary device.

So much in the way of negative argument as against the reputed differences between Biological and other methods. No such differences, I believe, really exist. The subject-matter of Biological science is different from that of other sciences, but the methods of all are identical; and these methods are—

1. *Observation* of facts—including under this head that *artificial observation* which is called *experiment.*

2. That process of tying up similar facts into bundles ticketed and ready for use, which is called *Comparison* and *Classification*—the results of the process, the ticketed bundles, being named *General propositions.*

3. *Deduction,* which takes us from the general proposition to facts again—teaches us, if I may so say, to anticipate from the ticket what is inside the bundle. And finally—

4. *Verification,* which is the process of ascertaining whether, in point of fact, our anticipation is a correct one.

Such are the methods of all science whatsoever; but perhaps you will permit me to give you an illustration of their employment in the science of Life; and I will take as a special case the establishment of the doctrine of the *Circulation of the Blood.*

In this case, *simple observation* yields us a knowledge of the existence of the blood from some accidental hæmorrhage, we will say; we may even grant that it informs us of the localisation of this blood in particular vessels, the heart, etc., from some accidental cut or the like. It teaches also the existence of a pulse in various parts of the body, and acquaints us with the structure of the heart and vessels.

Here, however, *simple observation* stops, and we must have recourse to *experiment.*

You tie a vein, and you find that the blood accumulates on the side of the ligature opposite the heart. You tie an artery, and you find that the blood accumulates on the side near the heart. Open the chest, and you see the heart contracting with great force. Make openings into its principal cavities, and you will find that all the blood flows out, and no more pressure is exerted on either side of the arterial or venous ligature.

Now, all these facts, taken together, constitute the evidence that the blood is propelled by the heart through the arteries, and returns by the veins—that, in short, the blood circulates.

Suppose our experiments and observations have been made on horses, then we group and ticket them into a general proposition, thus—*all horses have a circulation of their blood.*

Henceforward a horse is a sort of indication or label, telling us where we shall find a peculiar series of phænomena called the circulation of the blood.

Here is our *general proposition*, then.

How, and when, are we justified in making our next step—a *deduction* from it?

Suppose our physiologist, whose experience is limited to horses, meets with a zebra for the first time—will he suppose that this generalisation holds good for zebras also?

That depends very much on his turn of mind. But we will suppose him to be a bold man. He will say, "The zebra is certainly not a horse, but it is very like one—so like, that it must be the 'ticket' or mark of a blood-circulation also; and I conclude that the zebra has a circulation."

That is a deduction, a very fair deduction, but by no means to be considered scientifically secure. This last quality in fact can only be given by *verification*—that is, by making a zebra the subject of all the experiments performed on the horse. Of course, in the present case, the *deduction* would be *confirmed* by this process of verification, and the result would be, not merely a positive widening of knowledge, but a fair increase of confidence in the truth of one's generalisations in other cases.

Thus, having settled the point in the zebra and horse, our philosopher would have great confidence in the existence of a circulation in the ass. Nay, I fancy most persons would excuse him, if in this case he did not take the trouble to go through the process of verification at all; and it would not be without a parallel in the history of the human mind, if our imaginary physiologist now maintained that he was acquainted with asinine circulation *à priori*.

However, if I might impress any caution upon your

minds, it is, the utterly conditional nature of all our knowledge—the danger of neglecting the process of verification under any circumstances; and the film upon which we rest, the moment our deductions carry us beyond the reach of this great process of verification. There is no better instance of this than is afforded by the history of our knowledge of the circulation of the blood in the animal kingdom until the year 1824. In every animal possessing a circulation at all, which had been observed up to that time, the current of the blood was known to take one definite and invariable direction. Now, there is a class of animals called *Ascidians,* which possess a heart and a circulation, and up to the period of which I speak, no one would have dreamt of questioning the propriety of the deduction, that these creatures have a circulation in one direction; nor would any one have thought it worth while to verify the point. But, in that year, M. von Hasselt, happening to examine a transparent animal of this class, found, to his infinite surprise, that after the heart had beat a certain number of times, it stopped, and then began beating the opposite way—so as to reverse the course of the current, which returned by and by to its original direction.

I have myself timed the heart of these little animals. I found it as regular as possible in its periods of reversal: and I know no spectacle in the animal kingdom more wonderful than that which it presents—all the more wonderful that to this day it remains an unique fact, peculiar to this class among the whole animated world. At the same time I know of no more striking case of the necessity of the *verification* of even those deductions which seem founded on the widest and safest inductions.

Such are the methods of Biology—methods which are obviously identical with those of all other sciences, and

therefore wholly incompetent to form the ground of any distinction between it and them.[1]

But I shall be asked at once, Do you mean to say that there is no difference between the habit of mind of a mathematician and that of a naturalist? Do you imagine that Laplace might have been put into the Jardin des Plantes, and Cuvier into the Observatory, with equal advantage to the progress of the sciences they professed?

To which I would reply, that nothing could be further from my thoughts. But different habits and various special tendencies of two sciences do not imply different methods. The mountaineer and the man of the plains have very different habits of progression, and each would be at a loss in the other's place; but the method of progression, by putting one leg before the other, is the same in each case. Every step of each is a combination of a lift and a push; but the mountaineer lifts more and the lowlander pushes more. And I think the case of two sciences resembles this.

I do not question for a moment, that while the Mathematician is busy with deductions *from* general propositions, the Biologist is more especially occupied with observation, comparison, and those processes which lead *to* general propositions. All I wish to insist upon is, that this difference depends not on any fundamental distinction in the sciences themselves, but on the accidents of their subject-matter, of their relative complexity, and consequent relative perfection.

The Mathematician deals with two properties of objects only, number and extension, and all the inductions he wants have been formed and finished ages ago. He

[1] Save for the pleasure of doing so, I need hardly point out my obligations to Mr. J. S. Mill's *System of Logic*, in this view of scientific method.

is occupied now with nothing but deduction and verification.

The Biologist deals with a vast number of properties of objects, and his inductions will not be completed, I fear, for ages to come; but when they are, his science will be as deductive and as exact as the Mathematics themselves.

Such is the relation of Biology to those sciences which deal with objects having fewer properties than itself. But as the student, in reaching Biology, looks back upon sciences of a less complex and therefore more perfect nature; so, on the other hand, does he look forward to other more complex and less perfect branches of knowledge. Biology deals only with living beings as isolated things—treats only of the life of the individual: but there is a higher division of science still, which considers living beings as aggregates—which deals with the relation of living beings one to another—the science which *observes* men—whose *experiments* are made by nations one upon another, in battlefields—whose *general propositions* are embodied in history, morality, and religion—whose *deductions* lead to our happiness or our misery—and whose *verifications* so often come too late, and serve only

"To point a moral, or adorn a tale"—

I mean the science of Society or *Sociology*.

I think it is one of the grandest features of Biology, that it occupies this central position in human knowledge. There is no side of the human mind which physiological study leaves uncultivated. Connected by innumerable ties with abstract science, Physiology is yet in the most intimate relation with humanity; and by teaching us that law and order, and a definite scheme of development, regulate even the strangest and wildest manifestations of individual life, she prepares the student to look for a goal

even amidst the erratic wanderings of mankind, and to believe that history offers something more than an entertaining chaos—a journal of a toilsome, tragi-comic march nowhither.

The preceding considerations have, I hope, served to indicate the replies which befit the first two of the questions which I set before you at starting—viz., What is the range and position of Physiological Science as a branch of knowledge, and what is its value as a means of mental discipline?

Its *subject-matter* is a large moiety of the universe—its *position* is midway between the physico-chemical and the social sciences. Its *value* as a branch of discipline is partly that which it has in common with all sciences—the training and strengthening of common sense; partly that which is more peculiar to itself—the great exercise which it affords to the faculties of observation and comparison; and, I may add, the *exactness* of knowledge which it requires on the part of those among its votaries who desire to extend its boundaries.

If what has been said as to the position and scope of Biology be correct, our third question—What is the practical value of physiological instruction?—might, one would think, be left to answer itself.

On other grounds even, were mankind deserving of the title "rational," which they arrogate to themselves, there can be no question that they would consider, as the most necessary of all branches of instruction for themselves and for their children, that which professes to acquaint them with the conditions of the existence they prize so highly —which teaches them how to avoid disease and to cherish health, in themselves and those who are dear to them.

I am addressing, I imagine, an audience of educated persons; and yet I dare venture to assert that, with the ex-

ception of those of my hearers who may chance to have received a medical education, there is not one who could tell me what is the meaning and use of an act which he performs a score of times every minute, and whose suspension would involve his immediate death—I mean the act of breathing—or who could state in precise terms why it is that a confined atmosphere is injurious to health.

The *practical value* of Physiological knowledge! Why is it that educated men can be found to maintain that a slaughter-house in the midst of a great city is rather a good thing than otherwise?—that mothers persist in exposing the largest possible amount of surface of their children to the cold, by the absurd style of dress they adopt, and then marvel at the peculiar dispensation of Providence, which removes their infants by bronchitis and gastric fever? Why is it that quackery rides rampant over the land; and that not long ago, one of the largest public rooms in this great city could be filled by an audience gravely listening to the reverend expositor of the doctrine that the simple physiological phænomena known as spirit-rapping, table-turning, phreno-magnetism, and I know not what other absurd and inappropriate names, are due to the direct and personal agency of Satan?

Why is all this, except from the utter ignorance as to the simplest laws of their own animal life, which prevails among even the most highly educated persons in this country?

But there are other branches of Biological Science, besides Physiology proper, whose practical influence, though less obvious, is not, as I believe, less certain. I have heard educated men speak with an ill-disguised contempt of the studies of the naturalist, and ask, not without a shrug, "What is the use of knowing all about these miserable animals—what bearing has it on human life?"

I will endeavor to answer that question. I take it that all will admit there is definite Government of this universe—that its pleasures and pains are not scattered at random, but are distributed in accordance with orderly and fixed laws, and that it is only in accordance with all we know of the rest of the world, that there should be an agreement between one portion of the sensitive creation and another in these matters.

Surely then it interests us to know the lot of other animal creatures—however far below us, they are still the sole created things which share with us the capability of pleasure and the susceptibility to pain.

I cannot but think that he who finds a certain proportion of pain and evil inseparably woven up in the life of the very worms, will bear his own share with more courage and submission; and will, at any rate, view with suspicion those weakly amiable theories of the Divine government, which would have us believe pain to be an oversight and a mistake—to be corrected by and by. On the other hand, the predominance of happiness among living things—their lavish beauty—the secret and wonderful harmony which pervades them all, from the highest to the lowest, are equally striking refutations of that modern Manichean doctrine, which exhibits the world as a slave-mill, worked with many tears, for mere utilitarian ends.

There is yet another way in which natural history may, I am convinced, take a profound hold upon practical life—and that is, by its influence over our finer feelings, as the greatest of all sources of that pleasure which is derivable from beauty. I do not pretend that natural-history knowledge, as such, can increase our sense of the beautiful in natural objects. I do not suppose that the dead soul of Peter Bell, of whom the great poet of nature says,—

> A primrose by the river's brim,
> A yellow primrose was to him,—
> And it was nothing more,—

would have been a whit roused from its apathy by the information that the primrose is a Dicotyledonous Exogen, with a monopetalous corolla and central placentation. But I advocate natural-history knowledge from this point of view, because it would lead us to *seek* the beauties of natural objects, instead of trusting to chance to force them on our attention. To a person uninstructed in natural history, his country or sea-side stroll is a walk through a gallery filled with wonderful works of art, nine-tenths of which have their faces turned to the wall. Teach him something of natural history, and you place in his hands a catalogue of those which are worth turning round. Surely our innocent pleasures are not so abundant in this life, that we can afford to despise this or any other source of them. We should fear being banished for our neglect to that limbo, where the great Florentine tells us are those who, during this life, "wept when they might be joyful."

But I shall be trespassing unwarrantably on your kindness, if I do not proceed at once to my last point—the time at which Physiological Science should first form a part of the Curriculum of Education.

The distinction between the teaching of the facts of a science as instruction, and the teaching it systematically as knowledge, has already been placed before you in a previous lecture: and it appears to me that, as with other sciences, the *common facts* of Biology—the uses of parts of the body—the names and habits of the living creatures which surround us—may be taught with advantage to the youngest child. Indeed, the avidity of children for this kind of knowledge, and the comparative ease with which they retain it, is something quite marvellous. I doubt

whether any toy would be so acceptable to young children as a vivarium of the same kind as, but of course on a smaller scale than, those admirable devices in the Zoological Gardens.

On the other hand, systematic teaching in Biology cannot be attempted with success until the student has attained to a certain knowledge of physics and chemistry: for though the phænomena of life are dependent neither on physical nor on chemical, but on vital forces, yet they result in all sorts of physical and chemical changes, which can only be judged by their own laws.

And now to sum up in a few words the conclusions to which I hope you see reason to follow me.

Biology needs no apologist when she demands a place—and a prominent place—in any scheme of education worthy of the name. Leave out the Physiological sciences from your curriculum, and you launch the student into the world, undisciplined in that science whose subject-matter would best develop his powers of observation; ignorant of facts of the deepest importance for his own and others' welfare; blind to the richest sources of beauty in God's creation; and unprovided with that belief in a living law, and an order manifesting itself in and through endless change and variety, which might serve to check and moderate that phase of despair through which, if he take an earnest interest in social problems, he will assuredly sooner or later pass.

Finally, one word for myself. I have not hesitated to speak strongly where I have felt strongly; and I am but too conscious that the indicative and imperative moods have too often taken the place of the more becoming subjunctive and conditional. I feel, therefore, how necessary it is to beg you to forget the personality of him who has thus ventured to address you, and to consider only the truth or error in what has been said.

III

ON THE ADVISABLENESS OF IMPROVING NATURAL KNOWLEDGE

[1866]

[A lay sermon delivered at St. Martin's Hall, January 7, 1866. It sets forth the importance of the movement instituted by the foundation of the Royal Society in the latter part of the seventeenth century. "The aims, methods, and ideals of natural science are here luminously presented, and its wide-reaching influence in the future predicted with a confidence which has since been fully justified," says Mr. J. H. Ainsworth Davis; and Prof. William Keith Brooks declares this to be "a gem of English literature . . . worthy to be read in the schools as an illustration of the union of scientific knowledge with literary genius."

This is a good illustration of well-knit structure. The purpose of the essay is twofold: to show the effect of knowledge of nature on the formation of the views of men; and to show the necessary change of views with increasing knowledge of natural law. A careful study should be made of the relation of the parts of the essay to each other and to the whole. The unity in the scheme of treatment should be discovered. It offers studies in the technic of both exposition and argument.

It may be well to outline in detail the three paragraph groups which make up the introduction, stating in each case the theme and working out its development, showing the relation of the groups to each other, and indicating the rela-

tion of the whole to the rest of the essay. Good practice in argumentation is offered by working out in the form of briefs Huxley's two propositions: "natural knowledge, seeking to satisfy natural wants, has found the ideas which can alone still spiritual cravings"; and "natural knowledge, in desiring to ascertain the laws of comfort, has been driven to discover those of conduct, and to lay the foundation of a new morality."

This essay offers also an excellent opportunity for the study of Huxley's concreteness and vividness of style. His use of repetition, climax, and epigrammatic phrasing for securing emphasis and driving his point home, suggests a comparison with Macaulay. A study of Huxley's choice of words is also suggested.]

THIS time two hundred years ago—in the beginning of January, 1666—those of our forefathers who inhabited this great and ancient city, took breath between the shocks of two fearful calamities: one not quite past, although its fury had abated; the other to come.

Within a few yards of the very spot on which we are assembled, so the tradition runs, that painful and deadly malady, the plague, appeared in the latter months of 1664; and, though no new visitor, smote the people of England, and especially of her capital, with a violence unknown before, in the course of the following year. The hand of a master has pictured what happened in those dismal months; and in that truest of fictions, "The History of the Plague Year," Defoe shows death, with every accompaniment of pain and terror, stalking through the narrow streets of old London, and changing their busy hum into a silence broken only by the wailing of the mourners of fifty thousand dead; by the woeful denunciations and mad prayers of fanatics; and by the madder yells of despairing profligates.

But, about this time in 1666, the death-rate had sunk to nearly its ordinary amount; a case of plague occurred only here and there, and the richer citizens who had flown from the pest had returned to their dwellings. The remnant of the people began to toil at the accustomed round of duty, or of pleasure; and the stream of city life bid fair to flow back along its old bed, with renewed and uninterrupted vigor.

The newly-kindled hope was deceitful. The great plague, indeed, returned no more; but what it had done for the Londoners, the great fire, which broke out in the autumn of 1666, did for London; and, in September of that year, a heap of ashes and the indestructible energy of the people were all that remained of the glory of five-sixths of the city within the walls.

Our forefathers had their own ways of accounting for each of these calamities. They submitted to the plague in humility and in penitence, for they believed it to be the judgment of God. But towards the fire they were furiously indignant, interpreting it as the effect of the malice of man—as the work of the Republicans, or of the Papists, according as their prepossessions ran in favor of loyalty or of Puritanism.

It would, I fancy, have fared but ill with one who, standing where I now stand, in what was then a thickly-peopled and fashionable part of London, should have broached to our ancestors the doctrine which I now propound to you—that all their hypotheses were alike wrong; that the plague was no more, in their sense, Divine judgment, than the fire was the work of any political or of any religious sect; but that they were themselves the authors of both plague and fire, and that they must look to themselves to prevent the recurrence of calamities, to

all appearance so peculiarly beyond the reach of human control—so evidently the result of the wrath of God, or of the craft and subtlety of an enemy.

And one may picture to one's self how harmoniously the holy cursing of the Puritan of that day would have chimed in with the unholy cursing and the crackling wit of the Rochesters and Sedleys, and with the revilings of the political fanatics, if my imaginary plain dealer had gone on to say that, if the return of such misfortunes were ever rendered impossible, it would not be in virtue of the victory of the faith of Laud, or of that of Milton; and, as little, by the triumph of republicanism, as by that of monarchy. But that the one thing needful for compassing this end was, that the people of England should second the efforts of an insignificant corporation, the establishment of which, a few years before the epoch of the great plague and the great fire, had been as little noticed as they were conspicuous.

Some twenty years before the outbreak of the plague a few calm and thoughtful students banded themselves together for the purpose, as they phrased it, of "improving natural knowledge." The ends they proposed to attain cannot be stated more clearly than in the words of one of the founders of the organisation:

"Our business was (precluding matters of theology and state affairs) to discourse and consider of philosophical enquiries, and such as related thereunto—as Physick, Anatomy, Geometry, Astronomy, Navigation, Staticks, Magneticks, Chymicks, Mechanicks, and Natural Experiments; with the state of these studies and their cultivation at home and abroad. We then discoursed of the circulation of the blood, the valves in the veins, the venæ lacteæ, the lymphatic vessels, the Copernican hypothesis, the

nature of comets and new stars, the satellites of Jupiter, the oval shape (as it then appeared) of Saturn, the spots on the sun and its turning on its own axis, the inequalities and selenography of the moon, the several phases of Venus and Mercury, the improvement of telescopes and grinding of glasses for that purpose, the weight of air, the possibility or impossibility of vacuities and nature's abhorrence thereof, the Torricellian experiment in quicksilver, the descent of heavy bodies and the degree of acceleration therein, with divers other things of like nature, some of which were then but new discoveries, and others not so generally known and embraced as now they are; with other things appertaining to what hath been called the New Philosophy, which from the times of Galileo at Florence, and Sir Francis Bacon (Lord Verulam) in England, hath been much cultivated in Italy, France, Germany, and other parts abroad, as well as with us in England."

The learned Dr. Wallis, writing in 1696, narrates in these words what happened half a century before, or about 1645. The associates met at Oxford, in the rooms of Dr. Wilkins, who was destined to become a bishop; and subsequently coming together in London, they attracted the notice of the king. And it is a strange evidence of the taste for knowledge which the most obviously worthless of the Stuarts shared with his father and grandfather, that Charles the Second was not content with saying witty things about his philosophers, but did wise things with regard to them. For he not only bestowed upon them such attention as he could spare from his poodles and his mistresses, but, being in his usual state of impecuniosity, begged for them of the Duke of Ormond; and, that step being without effect, gave them Chelsea College, a charter, and a mace; crowning his favors in the best

way they could be crowned, by burdening them no further with royal patronage or state interference.

Thus it was that the half-dozen young men, studious of the "New Philosophy," who met in one another's lodgings in Oxford or in London, in the middle of the seventeenth century, grew in numerical and in real strength, until, in its latter part, the "Royal Society for the Improvement of Natural Knowledge" had already become famous, and had acquired a claim upon the veneration of Englishmen, which it has ever since retained, as the principal focus of scientific activity in our islands, and the chief champion of the cause it was formed to support.

It was by the aid of the Royal Society that Newton published his "Principia." If all the books in the world, except the "Philosophical Transactions," were destroyed, it is safe to say that the foundations of physical science would remain unshaken, and that the vast intellectual progress of the last two centuries would be largely, though incompletely, recorded. Nor have any signs of halting or of decrepitude manifested themselves in our own times. As in Dr. Wallis's days, so in these, "our business is, precluding theology and state affairs, to discourse and consider of philosophical enquiries." But our "Mathematick" is one which Newton would have to go to school to learn; our "Staticks, Mechanicks, Magneticks, Chymicks, and Natural Experiments" constitute a mass of physical and chemical knowledge, a glimpse at which would compensate Galileo for the doings of a score of inquisitorial cardinals; our "Physick" and "Anatomy" have embraced such infinite varieties of being, have laid open such new worlds in time and space, have grappled, not unsuccessfully, with such complex problems, that the eyes of Vesalius and of Harvey might be dazzled by the sight of the tree that has grown out of their grain of mustard seed.

The fact is perhaps rather too much, than too little, forced upon one's notice, nowadays, that all this marvellous intellectual growth has a no less wonderful expression in practical life; and that, in this respect, if in no other, the movement symbolised by the progress of the Royal Society stands without a parallel in the history of mankind.

A series of volumes as bulky as the "Transactions of the Royal Society" might possibly be filled with the subtle speculations of the Schoolmen; not improbably, the obtaining a mastery over the products of mediæval thought might necessitate an even greater expenditure of time and of energy than the acquirement of the "New Philosophy"; but though such work engrossed the best intellects of Europe for a longer time than has elapsed since the great fire, its effects were "writ in water," so far as our social state is concerned.

On the other hand, if the noble first President of the Royal Society could revisit the upper air and once more gladden his eyes with a sight of the familiar mace, he would find himself in the midst of a material civilisation more different from that of his day than that of the seventeenth was from that of the first century. And if Lord Brouncker's native sagacity had not deserted his ghost, he would need no long reflection to discover that all these great ships, these railways, these telegraphs, these factories, these printing-presses, without which the whole fabric of modern English society would collapse into a mass of stagnant and starving pauperism—that all these pillars of our State are but the ripples and the bubbles upon the surface of that great spiritual stream, the springs of which only, he and his fellows were privileged to see; and seeing, to recognise as that which it behooved them above all things to keep pure and undefiled.

It may not be too great a flight of imagination to conceive our noble *revenant* not forgetful of the great troubles of his own day, and anxious to know how often London had been burned down since his time, and how often the plague had carried off its thousands. He would have to learn that, although London contains tenfold the inflammable matter that it did in 1666; though, not content with filling our rooms with woodwork and light draperies, we must needs lead inflammable and explosive gases into every corner of our streets and houses, we never allow even a street to burn down. And if he asked how this had come about, we should have to explain that the improvement of natural knowledge has furnished us with dozens of machines for throwing water upon fires, any one of which would have furnished the ingenious Mr. Hooke, the first "curator and experimenter" of the Royal Society, with ample materials for discourse before half a dozen meetings of that body; and that, to say truth, except for the progress of natural knowledge, we should not have been able to make even the tools by which these machines are constructed. And, further, it would be necessary to add, that although severe fires sometimes occur and inflict great damage, the loss is very generally compensated by societies, the operations of which have been rendered possible only by the progress of natural knowledge in the direction of mathematics, and the accumulation of wealth in virtue of other natural knowledge.

But the plague? My Lord Brouncker's observation would not, I fear, lead him to think that Englishmen of the nineteenth century are purer in life, or more fervent in religious faith, than the generation which could produce a Boyle, an Evelyn, and a Milton. He might find the mud of society at the bottom, instead of at the top, but I fear that the sum total would be as deserving of swift

judgment as at the time of the Restoration. And it would be our duty to explain once more, and this time not without shame, that we have no reason to believe that it is the improvement of our faith, nor that of our morals, which keeps the plague from our city; but, again, that it is the improvement of our natural knowledge.

We have learned that pestilences will only take up their abode among those who have prepared unswept and ungarnished residences for them. Their cities must have narrow, unwatered streets foul with accumulated garbage. Their houses must be ill-drained, ill-lighted, ill-ventilated. Their subjects must be ill-washed, ill-fed, ill-clothed. The London of 1665 was such a city. The cities of the East, where plague has an enduring dwelling, are such cities. We, in later times, have learned somewhat of Nature, and partly obey her. Because of this partial improvement of our natural knowledge and of that fractional obedience, we have no plague; because that knowledge is still very imperfect and that obedience yet incomplete, typhoid is our companion and cholera our visitor. But it is not presumptuous to express the belief that, when our knowledge is more complete and our obedience the expression of our knowledge, London will count her centuries of freedom from typhoid and cholera, as she now gratefully reckons her two hundred years of ignorance of that plague which swooped upon her thrice in the first half of the seventeenth century.

Surely, there is nothing in these explanations which is not fully borne out by the facts? Surely, the principles involved in them are now admitted among the fixed beliefs of all thinking men? Surely, it is true that our countrymen are less subject to fire, famine, pestilence, and all the evils which result from a want of command over and due anticipation of the course of Nature, than

were the countrymen of Milton; and health, wealth, and well-being are more abundant with us than with them? But no less certainly is the difference due to the improvement of our knowledge of Nature, and the extent to which that improved knowledge has been incorporated with the household words of men, and has supplied the springs of their daily actions.

Granting for a moment, then, the truth of that which the depreciators of natural knowledge are so fond of urging, that its improvement can only add to the resources of our material civilisation; admitting it to be possible that the founders of the Royal Society themselves looked for no other reward than this, I cannot confess that I was guilty of exaggeration when I hinted, that to him who had the gift of distinguishing between prominent events and important events, the origin of a combined effort on the part of mankind to improve natural knowledge might have loomed larger than the Plague and have outshone the glare of the Fire; as a something fraught with a wealth of beneficence to mankind, in comparison with which the damage done by those ghastly evils would shrink into insignificance.

It is very certain that for every victim slain by the plague, hundreds of mankind exist and find a fair share of happiness in the world by the aid of the spinning jenny. And the great fire, at its worst, could not have burned the supply of coal, the daily working of which, in the bowels of the earth, made possible by the steam pump, gives rise to an amount of wealth to which the millions lost in old London are but as an old song.

But spinning jenny and steam pump are, after all, but toys, possessing an accidental value; and natural knowledge creates multitudes of more subtle contrivances, the

praises of which do not happen to be sung because they are not directly convertible into instruments for creating wealth. When I contemplate natural knowledge squandering such gifts among men, the only appropriate comparison I can find for her is, to liken her to such a peasant woman as one sees in the Alps, striding ever upward, heavily burdened, and with mind bent only on her home; but yet without effort and without thought, knitting for her children. Now stockings are good and comfortable things, and the children will undoubtedly be much the better for them; but surely it would be short-sighted, to say the least of it, to depreciate this toiling mother as a mere stocking-machine—a mere provider of physical comforts?

However, there are blind leaders of the blind, and not a few of them, who take this view of natural knowledge, and can see nothing in the bountiful mother of humanity but a sort of comfort-grinding machine. According to them, the improvement of natural knowledge always has been, and always must be, synonymous with no more than the improvement of the material resources and the increase of the gratifications of men.

Natural knowledge is, in their eyes, no real mother of mankind, bringing them up with kindness, and, if need be, with sternness, in the way they should go, and instructing them in all things needful for their welfare; but a sort of fairy godmother, ready to furnish her pets with shoes of swiftness, swords of sharpness, and omnipotent Aladdin's lamps, so that they may have telegraphs to Saturn, and see the other side of the moon, and thank God they are better than their benighted ancestors.

If this talk were true, I, for one, should not greatly care to toil in the service of natural knowledge. I think I would just as soon be quietly chipping my own flint

axe, after the manner of my forefathers, a few thousand years back, as be troubled with the endless malady of thought which now infests us all, for such reward. But I venture to say that such views are contrary alike to reason and to fact. Those who discourse in such fashion seem to me to be so intent upon trying to see what is above Nature, or what is behind her, that they are blind to what stares them in the face in her.

I should not venture to speak thus strongly if my justification were not to be found in the simplest and most obvious facts—if it needed more than an appeal to the most notorious truths to justify my assertion, that the improvement of natural knowledge, whatever direction it has taken, and however low the aims of those who may have commenced it—has not only conferred practical benefits on men, but, in so doing, has effected a revolution in their conceptions of the universe and of themselves, and has profoundly altered their modes of thinking and their views of right and wrong. I say that natural knowledge, seeking to satisfy natural wants, has found the ideas which can alone still spiritual cravings. I say that natural knowledge, in desiring to ascertain the laws of comfort, has been driven to discover those of conduct, and to lay the foundations of a new morality.

Let us take these points separately; and first, what great ideas has natural knowledge introduced into men's minds?

I cannot but think that the foundations of all natural knowledge were laid when the reason of man first came face to face with the facts of Nature; when the savage first learned that the fingers of one hand are fewer than those of both; that it is shorter to cross a stream than to head it; that a stone stops where it is unless it be moved,

and that it drops from the hand which lets it go; that light and heat come and go with the sun; that sticks burn away in a fire; that plants and animals grow and die; that if he struck his fellow savage a blow he would make him angry, and perhaps get a blow in return, while if he offered him a fruit he would please him, and perhaps receive a fish in exchange. When men had acquired this much knowledge, the outlines, rude though they were, of mathematics, of physics, of chemistry, of biology, of moral, economical, and political science, were sketched. Nor did the germ of religion fail when science began to bud. Listen to words which, though new, are yet three thousand years old:

> ". . . When in heaven the stars about the moon
> Look beautiful, when all the winds are laid,
> And every height comes out, and jutting peak
> And valley, and the immeasurable heavens
> Break open to their highest, and all the stars
> Shine, and the shepherd gladdens in his heart." [1]

If the half savage Greek could share our feelings thus far, it is irrational to doubt that he went further, to find as we do, that upon that brief gladness there follows a certain sorrow—the little light of awakened human intelligence shines so mere a spark amidst the abyss of the unknown and unknowable; seems so insufficient to do more than illuminate the imperfections that cannot be remedied, the aspirations that cannot be realised, of man's own nature. But in this sadness, this consciousness of the limitation of man, this sense of an open secret which he cannot penetrate, lies the essence of all religion;

[1] Need it be said that this is Tennyson's English for Homer's Greek?

and the attempt to embody it in the forms furnished by the intellect is the origin of the higher theologies.

Thus it seems impossible to imagine but that the foundations of all knowledge—secular or sacred—were laid when intelligence dawned, though the superstructure remained for long ages so slight and feeble as to be compatible with the existence of almost any general view respecting the mode of governance of the universe. No doubt, from the first, there were certain phænomena which, to the rudest mind, presented a constancy of occurrence, and suggested that a fixed order ruled, at any rate, among them. I doubt if the grossest of Fetish worshippers ever imagined that a stone must have a god within it to make it fall, or that a fruit had a god within it to make it taste sweet. With regard to such matters as these, it is hardly questionable that mankind from the first took strictly positive and scientific views.

But, with respect to all the less familiar occurrences which present themselves, uncultured man, no doubt, has always taken himself as the standard of comparison, as the center and measure of the world; nor could he well avoid doing so. And finding that his apparently uncaused will has a powerful effect in giving rise to many occurrences, he naturally enough ascribed other and greater events to other and greater volitions, and came to look upon the world and all that therein is, as the product of the volitions of persons like himself, but stronger, and capable of being appeased or angered, as he himself might be soothed or irritated. Through such conceptions of the plan and working of the universe all mankind have passed, or are passing. And we may now consider what has been the effect of the improvement of natural knowledge on the views of men who have reached this stage, and who have begun to cultivate natural knowledge with no desire but

that of "increasing God's honour and bettering man's estate."

For example, what could seem wiser, from a mere material point of view, more innocent, from a theological one, to an ancient people, than that they should learn the exact succession of the seasons, as warnings for their husbandmen; or the position of the stars, as guides to their rude navigators? But what has grown out of this search for natural knowledge of so merely useful a character? You all know the reply. Astronomy—which of all sciences has filled men's minds with general ideas of a character most foreign to their daily experience, and has, more than any other, rendered it impossible for them to accept the beliefs of their fathers. Astronomy—which tells them that this so vast and seemingly solid earth is but an atom among atoms, whirling, no man knows whither, through illimitable space; which demonstrates that what we call the peaceful heaven above us, is but that space, filled by an infinitely subtle matter whose particles are seething and surging, like the waves of an angry sea; which opens up to us infinite regions where nothing is known, or ever seems to have been known, but matter and force, operating according to rigid rules; which leads us to contemplate phænomena the very nature of which demonstrates that they must have had a beginning, and that they must have an end, but the very nature of which also proves that the beginning was, to our conceptions of time, infinitely remote, and that the end is as immeasurably distant.

But it is not alone those who pursue astronomy who ask for bread and receive ideas. What more harmless than the attempt to lift and distribute water by pumping it; what more absolutely and grossly utilitarian? Yet out of pumps grew the discussions about Nature's ab-

horrence of a vacuum; and then it was discovered that Nature does not abhor a vacuum, but that air has weight; and that notion paved the way for the doctrine that all matter has weight, and that the force which produces weight is co-extensive with the universe—in short, to the theory of universal gravitation and endless force. While learning how to handle gases led to the discovery of oxygen, and to modern chemistry, and to the notion of the indestructibility of matter.

Again, what simpler, or more absolutely practical, than the attempt to keep the axle of a wheel from heating when the wheel turns round very fast? How useful for carters and gig drivers to know something about this; and how good were it, if any ingenious person would find out the cause of such phænomena, and thence educe a general remedy for them. Such an ingenious person was Count Rumford; and he and his successors have landed us in the theory of the persistence, or indestructibility, of force. And in the infinitely minute, as in the infinitely great, the seekers after natural knowledge of the kinds called physical and chemical, have everywhere found a definite order and succession of events which seem never to be infringed.

And how has it fared with "Physick" and Anatomy? Have the anatomist, the physiologist, or the physician, whose business it has been to devote themselves assiduously to that eminently practical and direct end, the alleviation of the sufferings of mankind—have they been able to confine their vision more absolutely to the strictly useful? I fear they are the worst offenders of all. For if the astronomer has set before us the infinite magnitude of space, and the practical eternity of the duration of the universe; if the physical and chemical philosophers have demonstrated the infinite minuteness of its constituent

parts, and the practical eternity of matter and of force; and if both have alike proclaimed the universality of a definite and predicable order and succession of events, the workers in biology have not only accepted all these, but have added more startling theses of their own. For, as the astronomers discover in the earth no centre of the universe, but an eccentric speck, so the naturalists find man to be no centre of the living world, but one amidst endless modifications of life; and as the astronomer observes the mark of practically endless time set upon the arrangements of the solar system so the student of life finds the records of ancient forms of existence peopling the world for ages, which, in relation to human experience, are infinite.

Furthermore, the physiologist finds life to be as dependent for its manifestation on particular molecular arrangements as any physical or chemical phænomenon; and wherever he extends his researches, fixed order and unchanging causation reveal themselves, as plainly as in the rest of Nature.

Nor can I find that any other fate has awaited the germ of Religion. Arising, like all other kinds of knowledge, out of the action and interaction of man's mind, with that which is not man's mind, it has taken the intellectual coverings of Fetishism or Polytheism; of Theism or Atheism; of Superstition or Rationalism. With these, and their relative merits and demerits, I have nothing to do; but this it is needful for my purpose to say, that if the religion of the present differs from that of the past, it is because the theology of the present has become more scientific than that of the past; because it has not only renounced idols of wood and idols of stone, but begins to see the necessity of breaking in pieces the idols built up of books and traditions and fine-spun

ecclesiastical cobwebs; and of cherishing the noblest and most human of man's emotions, by worship "for the most part of the silent sort" at the altar of the Unknown.

Such are a few of the new conceptions implanted in our minds by the improvement of natural knowledge. Men have acquired the ideas of the practically infinite extent of the universe and of its practical eternity; they are familiar with the conception that our earth is but an infinitesimal fragment of that part of the universe which can be seen; and that, nevertheless, its duration is, as compared with our standards of time, infinite. They have further acquired the idea that man is but one of innumerable forms of life now existing on the globe, and that the present existences are but the last of an immeasurable series of predecessors. Moreover, every step they have made in natural knowledge has tended to extend and rivet in their minds the conception of a definite order of the universe—which is embodied in what are called, by an unhappy metaphor, the laws of Nature—and to narrow the range and loosen the force of men's belief in spontaneity, or in changes other than such as arise out of that definite order itself.

Whether these ideas are well or ill founded is not the question. No one can deny that they exist, and have been the inevitable outgrowth of the improvement of natural knowledge. And if so, it cannot be doubted that they are changing the form of men's most cherished and most important convictions.

And as regards the second point—the extent to which the improvement of natural knowledge has remodelled and altered what may be termed the intellectual ethics of men—what are among the moral convictions most fondly held by barbarous and semi-barbarous people.

They are the convictions that authority is the soundest basis of belief; that merit attaches to a readiness to believe; that the doubting disposition is a bad one, and scepticism a sin; that when good authority has pronounced what is to be believed, and faith has accepted it, reason has no further duty. There are many excellent persons who yet hold by these principles, and it is not my present business, or intention, to discuss their views. All I wish to bring clearly before your minds is the unquestionable fact, that the improvement of natural knowledge is effected by methods which directly give the lie to all these convictions, and assume the exact reverse of each to be true.

The improver of natural knowledge absolutely refuses to acknowledge authority, as such. For him, scepticism is the highest of duties; blind faith the one unpardonable sin. And it cannot be otherwise, for every great advance in natural knowledge has involved the absolute rejection of authority, the cherishing of the keenest scepticism, the annihilation of the spirit of blind faith; and the most ardent votary of science holds his firmest convictions, not because the men he most venerates hold them; not because their verity is testified by portents and wonders; but because his experience teaches him that whenever he chooses to bring these convictions into contact with their primary source, Nature—whenever he thinks fit to test them by appealing to experiment and to observation—Nature will confirm them. The man of science has learned to believe in justification, not by faith, but by verification.

Thus, without for a moment pretending to despise the practical results of the improvement of natural knowledge, and its beneficial influence on material civilisation, it must, I think, be admitted that the great ideas, some of which I have indicated, and the ethical spirit which I have endeav-

oured to sketch, in the few moments which remained at my disposal, constitute the real and permanent significance of natural knowledge.

If these ideas be destined, as I believe they are, to be more and more firmly established as the world grows older; if that spirit be fated, as I believe it is, to extend itself into all departments of human thought, and to become co-extensive with the range of knowledge; if, as our race approaches its maturity, it discovers, as I believe it will, that there is but one kind of knowledge and but one method of acquiring it; then we, who are still children, may justly feel it our highest duty to recognise the advisableness of improving natural knowledge, and so to aid ourselves and our successors in our course towards the noble goal which lies before mankind.

IV

A LIBERAL EDUCATION: AND WHERE TO FIND IT

[1868]

[The opening address, delivered as Principal of the South London Working Men's College, January 4, 1868. "This is not a brief for science to the exclusion of other teaching; no essay has insisted more strenuously on the evils of a one-sided education, whether it be classical or scientific; but it urged the necessity for a strong tincture of science and her method, if the modern conception of the world, created by the spread of natural knowledge, is to be fairly understood," says Mr. Leonard Huxley in his *Life*.

This essay is a study in exposition by means of definition. The plan is clear-cut; the analysis readily made. It may be well to outline the essay, dividing according to the ideas suggested by the title. A study should be made of the purpose underlying Huxley's indictment of English education, elementary, secondary, and university; of the reason for the praise of German education; of the application of the points made to the new institution which Huxley is formally opening. His definition of education, his distinction between natural and artificial education, and his ideal of a liberal education should be committed to memory.

Here, too, it may be profitable to make a definite study of Huxley's words and sentences. Another interesting study is offered in this essay by the figures of speech, especially the metaphor comparing life to a game of chess, and

the figures used in describing the education of man by Nature.]

THE business which the South London Working Men's College has undertaken is a great work; indeed, I might say, that Education, with which that college proposes to grapple, is the greatest work of all those which lie ready to a man's hand just at present.

And, at length, this fact is becoming generally recognised. You cannot go anywhere without hearing a buzz of more or less confused and contradictory talk on this subject—nor can you fail to notice that, in one point at any rate, there is a very decided advance upon like discussions in former days. Nobody outside the agricultural interest now dares to say that education is a bad thing. If any representative of the once large and powerful party, which, in former days, proclaimed this opinion, still exists in the semi-fossil state, he keeps his thoughts to himself. In fact, there is a chorus of voices, almost distressing in their harmony, raised in favor of the doctrine that education is the great panacea for human troubles, and that, if the country is not shortly to go to the dogs, everybody must be educated.

The politicians tell us, "You must educate the masses because they are going to be masters." The clergy join in the cry for education, for they affirm that the people are drifting away from church and chapel into the broadest infidelity. The manufacturers and the capitalists swell the chorus lustily. They declare that ignorance makes bad workmen; that England will soon be unable to turn out cotton goods, or steam engines, cheaper than other people; and then, Ichabod! Ichabod! the glory will be departed from us. And a few voices are lifted up in favor of the doctrine that the masses should be educated

because they are men and women with unlimited capacities of being, doing, and suffering, and that it is as true now, as it ever was, that the people perish for lack of knowledge.

These members of the minority, with whom I confess I have a good deal of sympathy, are doubtful whether any of the other reasons urged in favor of the education of the people are of much value—whether, indeed, some of them are based upon either wise or noble grounds of action. They question if it be wise to tell people that you will do for them, out of fear of their power, what you have left undone, so long as your only motive was compassion for their weakness and their sorrows. And, if ignorance of everything which it is needful a ruler should know is likely to do so much harm in the governing classes of the future, why is it, they ask reasonably enough, that such ignorance in the governing classes of the past has not been viewed with equal horror?

Compare the average artisan and the average country squire, and it may be doubted if you will find a pin to choose between the two in point of ignorance, class feeling, or prejudice. It is true that the ignorance is of a different sort—that the class feeling is in favour of a different class—and that the prejudice has a distinct savour of wrong-headedness in each case—but it is questionable if the one is either a bit better, or a bit worse, than the other. The old protectionist theory is the doctrine of trades unions as applied by the squires, and the modern trades unionism is the doctrine of the squires applied by the artisans. Why should we be worse off under one *régime* than under the other?

Again, this sceptical minority asks the clergy to think whether it is really want of education which keeps the masses away from their ministrations—whether the most completely educated men are not as open to reproach on

this score as the workmen; and whether, perchance, this may not indicate that it is not education which lies at the bottom of the matter?

Once more, these people, whom there is no pleasing, venture to doubt whether the glory which rests upon being able to undersell all the rest of the world, is a very safe kind of glory—whether we may not purchase it too dear; especially if we allow education, which ought to be directed to the making of men, to be diverted into a process of manufacturing human tools, wonderfully adroit in the exercise of some technical industry, but good for nothing else.

And finally, these people inquire whether it is the masses alone who need a reformed and improved education. They ask whether the richest of our public schools might not well be made to supply knowledge, as well as gentlemanly habits, a strong class feeling, and eminent proficiency in cricket. They seem to think that the noble foundations of our old universities are hardly fulfilling their functions in their present posture of half clerical seminaries, half race-courses, where men are trained to win a senior wranglership, or a double-first, as horses are trained to win a cup, with as little reference to the needs of after-life in the case of a man as in that of the racer. And, while as zealous for education as the rest, they affirm that, if the education of the richer classes were such as to fit them to be the leaders and the governors of the poorer; and, if the education of the poorer classes were such as to enable them to appreciate really wise guidance and good governance, the politicians need not fear mob-law, nor the clergy lament their want of flocks, nor the capitalists prognosticate the annihilation of the prosperity of the country.

Such is the diversity of opinion upon the why and the

wherefore of education. And my hearers will be prepared to expect that the practical recommendations which are put forward are not less discordant. There is a loud cry for compulsory education. We English, in spite of constant experience to the contrary, preserve a touching faith in the efficacy of acts of Parliament; and I believe we should have compulsory education in the course of next session, if there were the least probability that half a dozen leading statesmen of different parties would agree what that education should be.

Some hold that education without theology is worse than none. Others maintain, quite as strongly, that education with theology is in the same predicament. But this is certain, that those who hold the first opinion can by no means agree what theology should be taught; and that those who maintain the second are in a small minority.

At any rate "make people learn to read, write, and cipher," say a great many; and the advice is undoubtedly sensible as far as it goes. But, as has happened to me in former days, those who, in despair of getting anything better, advocate this measure, are met with the objection that it is very like making a child practice the use of a knife, fork and spoon, without giving it a particle of meat. I really don't know what reply is to be made to such an objection.

But it would be unprofitable to spend more time in disentangling, or rather in showing up the knots in, the ravelled skeins of our neighbours. Much more to the purpose is it to ask if we possess any clue of our own which may guide us among these entanglements. And by way of a beginning, let us ask ourselves—What is education? Above all things, what is our ideal of a thoroughly liberal education?—of that education which, if we could begin

life again, we would give ourselves—of that education which, if we could mould the fates to our own will, we would give our children? Well, I know not what may be your conceptions upon this matter, but I will tell you mine, and I hope I shall find that our views are not very discrepant.

Suppose it were perfectly certain that the life and fortune of every one of us would, one day or other, depend upon his winning or losing a game of chess. Don't you think that we should all consider it to be a primary duty to learn at least the names and the moves of the pieces; to have a notion of a gambit, and a keen eye for all the means of giving and getting out of check? Do you not think that we should look with a disapprobation amounting to scorn, upon the father who allowed his son, or the state which allowed its members, to grow up without knowing a pawn from a knight?

Yet it is a very plain and elementary truth, that the life, the fortune, and the happiness of every one of us, and, more or less, of those who are connected with us, do depend upon our knowing something of the rules of a game infinitely more difficult and complicated than chess. It is a game which has been played for untold ages, every man and woman of us being one of the two players in a game of his or her own. The chess-board is the world, the pieces are the phænomena of the universe, the rules of the game are what we call the laws of Nature. The player on the other side is hidden from us. We know that his play is always fair, just, and patient. But also we know, to our cost, that he never overlooks a mistake, or makes the smallest allowance for ignorance. To the man who plays well, the highest stakes are paid, with that sort of overflowing generosity with which the strong shows

delight in strength. And one who plays ill is checkmated —without haste, but without remorse.

My metaphor will remind some of you of the famous picture in which Retzsch has depicted Satan playing at chess with man for his soul. Substitute for the mocking fiend in that picture a calm, strong angel who is playing for love, as we say, and would rather lose than win—and I should accept it as an image of human life.

Well, what I mean by Education is learning the rules of this mighty game. In other words, education is the instruction of the intellect in the laws of Nature, under which name I include not merely things and their forces, but men and their ways; and the fashioning of the affections and of the will into an earnest and loving desire to move in harmony with those laws. For me, education means neither more nor less than this. Anything which professes to call itself education must be tried by this standard, and if it fails to stand the test, I will not call it education, whatever may be the force of authority, or of numbers, upon the other side.

It is important to remember that, in strictness, there is no such thing as an uneducated man. Take an extreme case. Suppose that an adult man, in the full vigor of his faculties, could be suddenly placed in the world, as Adam is said to have been, and then left to do as he best might. How long would he be left uneducated? Not five minutes. Nature would begin to teach him, through the eye, the ear, the touch, the properties of objects. Pain and pleasure would be at his elbow telling him to do this and avoid that; and by slow degrees the man would receive an education which, if narrow, would be thorough, real, and adequate to his circumstances, though there would be no extras and very few accomplishments.

And if to this solitary man entered a second Adam, or

better still, an Eve, a new and greater world, that of social and moral phænomena, would be revealed. Joys and woes, compared with which all others might seem but faint shadows, would spring from the new relations. Happiness and sorrow would take the place of the coarser monitors, pleasure and pain; but conduct would still be shaped by the observation of the natural consequences of actions; or, in other words, by the laws of the nature of man.

To every one of us the world was once as fresh and new as to Adam. And then, long before we were susceptible of any other modes of instruction, Nature took us in hand, and every minute of waking life brought its educational influence, shaping our actions into rough accordance with Nature's laws, so that we might not be ended untimely by too gross disobedience. Nor should I speak of this process of education as past for any one, be he as old as he may. For every man the world is as fresh as it was at the first day, and as full of untold novelties for him who has the eyes to see them. And Nature is still continuing her patient education of us in that great university, the universe, of which we are all members—Nature having no Test-Acts.

Those who take honors in Nature's university, who learn the laws which govern men and things and obey them, are the really great and successful men in this world. The great mass of mankind are the "Poll," who pick up just enough to get through without much discredit. Those who won't learn at all are plucked; and then you can't come up again. Nature's pluck means extermination.

Thus the question of compulsory education is settled so far as Nature is concerned. Her bill on that question was framed and passed long ago. But, like all compulsory

legislation, that of Nature is harsh and wasteful in its operation. Ignorance is visited as sharply as willful disobedience—incapacity meets with the same punishment as crime. Nature's discipline is not even a word and a blow, and the blow first; but the blow without the word. It is left to you to find out why your ears are boxed.

The object of what we commonly call education—that education in which man intervenes and which I shall distinguish as artificial education—is to make good these defects in Nature's methods; to prepare the child to receive Nature's education, neither incapably nor ignorantly, nor with willful disobedience; and to understand the preliminary symptoms of her pleasure, without waiting for the box on the ear. In short, all artificial education ought to be an anticipation of natural education. And a liberal education is an artificial education which has not only prepared a man to escape the great evils of disobedience to natural laws, but has trained him to appreciate and to seize upon the rewards, which Nature scatters with as free a hand as her penalties.

That man, I think, has had a liberal education who has been so trained in youth that his body is the ready servant of his will, and does with ease and pleasure all the work that, as a mechanism, it is capable of; whose intellect is a clear, cold, logic engine, with all its parts of equal strength, and in smooth working order; ready, like a steam-engine, to be turned to any kind of work, and spin the gossamers as well as forge the anchors of the mind; whose mind is stored with a knowledge of the great and fundamental truths of Nature and of the laws of her operations; one who, no stunted ascetic, is full of life and fire, but whose passions are trained to come to heel by a vigorous will, the servant of a tender conscience; who has learned to love all beauty, whether of

Nature or of art, to hate all vileness, and to respect others as himself.

Such an one and no other, I conceive, has had a liberal education; for he is, as completely as a man can be, in harmony with Nature. He will make the best of her, and she of him. They will get on together rarely; she as his ever beneficent mother; he as her mouthpiece, her conscious self, her minister and interpreter.

Where is such an education as this to be had? Where is there any approximation to it? Has any one tried to found such an education? Looking over the length and breadth of these islands, I am afraid that all these questions must receive a negative answer. Consider our primary schools and what is taught in them. A child learns—

1. To read, write, and cipher, more or less well; but in a very large proportion of cases not so well as to take pleasure in reading, or to be able to write the commonest letter properly.

2. A quantity of dogmatic theology, of which the child, nine times out of ten, understands next to nothing.

3. Mixed up with this, so as to seem to stand or fall with it, a few of the broadest and simplest principles of morality. This, to my mind, is much as if a man of science should make the story of the fall of the apple in Newton's garden an integral part of the doctrine of gravitation, and teach it as of equal authority with the law of the inverse squares.

4. A good deal of Jewish history and Syrian geography, and perhaps a little something about English history and the geography of the child's own country. But I doubt if there is a primary school in England in which hangs a map of the hundred in which the village lies, so that the children may be practically taught by it what a map means.

5. A certain amount of regularity, attentive obedience, respect for others: obtained by fear, if the master be incompetent or foolish; by love and reverence, if he be wise.

So far as this school course embraces a training in the theory and practice of obedience to the moral laws of nature, I gladly admit, not only that it contains a valuable educational element, but that, so far, it deals with the most valuable and important part of all education. Yet, contrast what is done in this direction with what might be done; with the time given to matters of comparatively no importance; with the absence of any attention to things of the highest moment; and one is tempted to think of Falstaff's bill and "the halfpenny worth of bread to all that quantity of sack."

Let us consider what a child thus "educated" knows, and what it does not know. Begin with the most important topic of all—morality, as the guide of conduct. The child knows well enough that some acts meet with approbation and some with disapprobation. But it has never heard that there lies in the nature of things a reason for every moral law, as cogent and as well defined as that which underlies every physical law; that stealing and lying are just as certain to be followed by evil consequences as putting your hand in the fire, or jumping out of a garret window. Again, though the scholar may have been made acquainted, in dogmatic fashion, with the broad laws of morality, he has had no training in the application of those laws to the difficult problems which result from the complex conditions of modern civilisation. Would it not be very hard to expect any one to solve a problem in conic sections who had merely been taught the axioms and definitions of mathematical science?

A workman has to bear hard labor, and perhaps privation, while he sees others rolling in wealth, and feeding

their dogs with what would keep his children from starvation. Would it not be well to have helped that man to calm the natural promptings of discontent by showing him, in his youth, the necessary connection of the moral law which prohibits stealing with the stability of society— by proving to him, once for all, that it is better for his own people, better for himself, better for future generations, that he should starve than steal? If you have no foundation of knowledge, or habit of thought, to work upon, what chance have you of persuading a hungry man that a capitalist is not a thief "with a circumbendibus?" And if he honestly believes that, of what avail is it to quote the commandment against stealing, when he proposes to make the capitalist disgorge?

Again, the child learns absolutely nothing of the history or the political organisation of his own country. His general impression is, that everything of much importance happened a very long while ago; and that the Queen and the gentlefolks govern the country much after the fashion of King David and the elders and nobles of Israel—his sole models. Will you give a man with this much information a vote? In easy times he sells it for a pot of beer. Why should he not? It is of about as much use to him as a chignon, and he knows as much what to do with it, for any other purpose. In bad times, on the contrary, he applies his simple theory of government, and believes that his rulers are the cause of his sufferings—a belief which sometimes bears remarkable practical fruits.

Least of all, does the child gather from this primary "education" of ours a conception of the laws of the physical world, or of the relations of cause and effect therein. And this is the more to be lamented, as the poor are especially exposed to physical evils, and are more interested in removing them than any other class of the

community. If anyone is concerned in knowing the ordinary laws of mechanics one would think it is the hand-labourer, whose daily toil lies among levers and pulleys: or among the other implements of artisan work. And if any one is interested in the laws of health, it is the poor workman, whose strength is wasted by ill-prepared food, whose health is sapped by bad ventilation and bad drainage, and half whose children are massacred by disorders which might be prevented. Not only does our present primary education carefully abstain from hinting to the workmen that some of his greatest evils are traceable to mere physical agencies, which could be removed by energy, patience, and frugality; but it does worse—it renders him, so far as it can, deaf to those who could help him, and tries to substitute an Oriental submission to what is falsely declared to be the will of God, for his natural tendency to strive after a better condition.

What wonder, then, if very recently an appeal has been made to statistics for the profoundly foolish purpose of showing that education is of no good—that it diminishes neither misery nor crime among the masses of mankind? I reply, why should the thing which has been called education do either the one or the other? If I am a knave or a fool, teaching me to read and write won't make me less of either one or the other—unless somebody shows me how to put my reading and writing to wise and good purposes.

Suppose anyone were to argue that medicine is of no use, because it could be proved statistically that the percentage of deaths was just the same among people who had been taught how to open a medicine chest, and among those who did not so much as know the key by sight. The argument is absurd; but it is not more preposterous than that against which I am contending. The only

medicine for suffering, crime, and all the other woes of mankind, is wisdom. Teach a man to read and write, and you have put into his hands the great keys of the wisdom box. But it is quite another matter whether he ever opens the box or not. And he is as likely to poison as to cure himself, if, without guidance, he swallows the first drug that comes to hand. In these times a man may as well be purblind, as unable to read—lame, as unable to write. But I protest that, if I thought the alternative were a necessary one, I would rather that the children of the poor should grow up ignorant of both these mighty arts, than that they should remain ignorant of that knowledge to which these arts are means.

It may be said that all these animadversions may apply to primary schools, but that the higher schools, at any rate, must be allowed to give a liberal education. In fact they professedly sacrifice everything else to this object.

Let us inquire into this matter. What do the higher schools, those to which the great middle class of the country sends its children, teach, over and above the instruction given in the primary schools? There is a little more reading and writing of English. But, for all that, every one knows that it is a rare thing to find a boy of the middle or upper classes who can read aloud decently, or who can put his thoughts on paper in clear and grammatical (to say nothing of good or elegant) language. The "ciphering" of the lower schools expands into elementary mathematics in the higher; into arithmetic, with a little algebra, a little Euclid. But I doubt if one boy in five hundred has ever heard the explanation of a rule of arithmetic, or knows his Euclid otherwise than by rote.

Of theology, the middle-class schoolboy gets rather

less than poorer children, less absolutely and less relatively, because there are so many other claims upon his attention. I venture to say that, in the great majority of cases, his ideas on this subject when he leaves school are of the most shadowy and vague description, and associated with painful impressions of the weary hours spent in learning collects and catechism by heart.

Modern geography, modern history, modern literature; the English language as a language; the whole circle of the sciences, physical, moral, and social, are even more completely ignored in the higher than in the lower schools. Up till within a few years back, a boy might have passed through any one of the great public schools with the greatest distinction and credit, and might never so much as have heard of one of the subjects I have just mentioned. He might never have heard that the earth goes round the sun; that England underwent a great revolution in 1688, and France another in 1789; that there once lived certain notable men called Chaucer, Shakespeare, Milton, Voltaire, Goethe, Schiller. The first might be a German and the last an Englishman for anything he could tell you to the contrary. And as for Science, the only idea the word would suggest to his mind would be dexterity in boxing.

I have said that this was the state of things a few years back, for the sake of the few righteous who are to be found among the educational cities of the plain. But I would not have you too sanguine about the result, if you sound the minds of the existing generation of public schoolboys, on such topics as those I have mentioned.

Now let us pause to consider this wonderful state of affairs; for the time will come when Englishmen will quote it as the stock example of the stolid stupidity of their ancestors in the nineteenth century. The most thor-

oughly commercial people, the greatest voluntary wanderers and colonists the world has ever seen, are precisely the middle class of this country. If there be a people which has been busy making history on the great scale for the last three hundred years—and the most profoundly interesting history—history which, if it happened to be that of Greece or Rome, we should study with avidity—it is the English. If there be a people which, during the same period, has developed a remarkable literature, it is our own. If there be a nation whose prosperity depends absolutely and wholly upon their mastery over the forces of Nature, upon their intelligent apprehension of and obedience to the laws of the creation and distribution of wealth, and of the stable equilibrium of the forces of society, it is precisely this nation. And yet this is what these wonderful people tell their sons: "At the cost of from one to two thousand pounds of our hard-earned money, we devote twelve of the most precious years of your lives to school. There you shall toil, or be supposed to toil; but there you shall not learn one single thing of all those you will most want to know directly you leave school and enter upon the practical business of life. You will in all probability go into business, but you shall not know where, or how, any article of commerce is produced, or the difference between an export or an import, or the meaning of the word 'capital.' You will very likely settle in a colony, but you shall not know whether Tasmania is part of New South Wales, or *vice versa.*

"Very probably you may become a manufacturer, but you shall not be provided with the means of understanding the working of one of your own steam-engines, or the nature of the raw products you employ; and, when you are asked to buy a patent, you shall not have the slightest means of judging whether the inventor is an impostor who

is contravening the elementary principles of science, or a man who will make you as rich as Crœsus.

"You will very likely get into the House of Commons. You will have to take your share in making laws which may prove a blessing or a curse to millions of men. But you shall not hear one word respecting the political organisation of your country; the meaning of the controversy between free-traders and protectionists shall never have been mentioned to you; you shall not so much as know that there are such things as economical laws.

"The mental power which will be of most importance in your daily life will be the power of seeing things as they are without regard to authority; and of drawing accurate general conclusions from particular facts. But at school and at college you shall know of no source of truth but authority; nor exercise your reasoning faculty upon anything but deduction from that which is laid down by authority.

"You will have to weary your soul with work, and many a time eat your bread in sorrow and in bitterness, and you shall not have learned to take refuge in the great source of pleasure without alloy, the serene resting-place for worn human nature—the world of art."

Said I not rightly that we are a wonderful people? I am quite prepared to allow that education entirely devoted to these omitted subjects might not be a completely liberal education. But is an education which ignores them all a liberal education? Nay, is it too much to say that the education which should embrace these subjects and no others would be a real education, though an incomplete one; while an education which omits them is really not an education at all, but a more or less useful course of intellectual gymnastics?

For what does the middle-class school put in the place

of all these things which are left out? It substitutes what is usually comprised under the compendious title of the "classics"—that is to say, the languages, the literature, and the history of the ancient Greeks and Romans, and the geography of so much of the world as was known to these two great nations of antiquity. Now, do not expect me to depreciate the earnest and enlightened pursuit of classical learning. I have not the least desire to speak ill of such occupations, nor any sympathy with them who run them down. On the contrary, if my opportunities had lain in that direction, there is no investigation into which I could have thrown myself with greater delight than that of antiquity.

What science can present greater attractions than philology? How can a lover of literary excellence fail to rejoice in the ancient masterpieces? And with what consistency could I, whose business lies so much in the attempt to decipher the past, and to build up intelligible forms out of the scattered fragments of long-extinct beings, fail to take a sympathetic, though an unlearned, interest in the labors of a Niebuhr, a Gibbon, or a Grote? Classical history is a great section of the palæontology of man; and I have the same double respect for it as for other kinds of palæontology—that is to say, a respect for the facts which it establishes, as for all facts, and a still greater respect for it as a preparation for the discovery of a law of progress.

But if the classics were taught as they might be taught —if boys and girls were instructed in Greek and Latin, not merely as languages, but as illustrations of philological science; if a vivid picture of life on the shores of the Mediterranean two thousand years ago were imprinted on the minds of scholars; if ancient history were taught, not as a weary series of feuds and fights, but traced to its

causes in such men placed under such conditions; if, lastly, the study of the classical books were followed in such a manner as to impress boys with their beauties, and with the grand simplicity of their statement of the everlasting problems of human life, instead of with their verbal and grammatical peculiarities, I still think it as little proper that they should form the basis of a liberal education for our contemporaries, as I should think it fitting to make that sort of palæontology with which I am familiar the backbone of modern education.

It is wonderful how close a parallel to classical training could be made out of that palæontology to which I refer. In the first place, I could get up an osteological primer so arid, so pedantic in its terminology, so altogether distasteful to the youthful mind, as to beat the recent famous production of the head-masters out of the field in all these excellences. Next, I could exercise my boys upon easy fossils, and bring out all their powers of memory and all their ingenuity in the application of my osteo-grammatical rules to the interpretation, or construing, of those fragments. To those who had reached the higher classes, I might supply odd bones to be built up into animals, giving great honour and reward to him who succeeded in fabricating monsters most entirely in accordance with the rules. That would answer to verse making and essay writing in the dead languages.

To be sure, if a great comparative anatomist were to look at these fabrications he might shake his head, or laugh. But what then? Would such a catastrophe destroy the parallel? What, think you, would Cicero, or Horace, say to the production of the best sixth form going? And would not Terence stop his ears and run out if he could be present at an English performance of his own plays? Would *Hamlet,* in the mouths of a set

of French actors, who should insist on pronouncing English after the fashion of their own tongue, be more hideously ridiculous?

But it will be said that I am forgetting the beauty, and the human interest, which appertain to classical studies. To this I reply that it is only a very strong man who can appreciate the charms of a landscape as he is toiling up a steep hill, along a bad road. What with short-windedness, stones, ruts, and a pervading sense of the wisdom of rest and be thankful, most of us have little enough sense of the beautiful under these circumstances. The ordinary schoolboy is precisely in this case. He finds Parnassus uncommonly steep, and there is no chance of his having much time or inclination to look about him till he gets to the top. And nine times out of ten he does not get to the top.

But if this be a fair picture of the results of classical teaching at its best—and I gather from those who have authority to speak on such matters that it is so—what is to be said of classical teaching at its worst, or, in other words, of the classics of our ordinary middle-class schools? [1] I will tell you. It means getting up endless forms and rules by heart. It means turning Latin and Greek into English, for the mere sake of being able to do it, and without the smallest regard to the worth, or worthlessness, of the author read. It means the learning of innumerable, not always decent, fables in such a shape that the meaning they once had is dried up into utter trash; and the only impression left upon a boy's mind is, that the people who believed such things must have been the greatest idiots the world ever saw. And it means, finally, that after a

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[1] For a justification of what is here said about these schools, see that valuable book, *Essays on a Liberal Education, passim.*

dozen years spent at this kind of work, the sufferer shall be incompetent to interpret a passage in an author he has not already got up; that he shall loathe the sight of a Greek or Latin book; and that he shall never open, or think of, a classical writer again until, wonderful to relate, he insists upon submitting his sons to the same process.

These be your gods, O Israel! For the sake of this net result (and respectability) the British father denies his children all the knowledge they might turn to account in life, not merely for the achievement of vulgar success, but for guidance in the great crises of human existence. This is the stone he offers to those whom he is bound by the strongest and tenderest ties to feed with bread.

If primary and secondary education are in this unsatisfactory state, what is to be said to the universities? This is an awful subject, and one I almost fear to touch with my unhallowed hands; but I can tell you what those say who have authority to speak.

The Rector of Lincoln College, in his lately published valuable "Suggestions for Academical Organisation with especial reference to Oxford," tells us (p. 172):—

"The colleges were, in their origin, endowments, not for the elements of a general liberal education, but for the prolonged study of special and professional faculties by men of riper age. The universities embraced both these objects. The colleges, while they incidentally aided in elementary education, were specially devoted to the highest learning. . . .

"This was the theory of the middle-age university and the design of collegiate foundations in their origin. Time and circumstances have brought about a total change. The colleges no longer promote the researches of science, or

direct professional study. Here and there college walls may shelter an occasional student, but not in larger proportions than may be found in private life. Elementary teaching of youths under twenty is now the only function performed by the university, and almost the only object of college endowments. Colleges were homes for the life-study of the highest and most abstruse parts of knowledge. They have become boarding schools in which the elements of the learned languages are taught to youths."

If Mr. Pattison's high position, and his obvious love and respect for his university, be insufficient to convince the outside world that language so severe is yet no more than just, the authority of the Commissioners who reported on the University of Oxford in 1850 is open to no challenge. Yet they write:—

"It is generally acknowledged that both Oxford and the country at large suffer greatly from the absence of a body of learned men devoting their lives to the cultivation of science, and to the direction of academical education.

"The fact that so few books of profound research emanate from the University of Oxford, materially impairs its character as a seat of learning, and consequently its hold on the respect of the nation."

Cambridge can claim no exemption from the reproaches addressed to Oxford. And thus there seems no escape from the admission that what we fondly call our great seats of learning are simply "boarding schools" for bigger boys; that learned men are not more numerous in them than out of them; that the advancement of knowledge is not the object of fellows of colleges; that, in the philosophic calm and meditative stillness of their greenswarded courts, philosophy does not thrive, and meditation bears few fruits.

It is my great good fortune to reckon amongst my friends

resident members of both universities, who are men of learning and research, zealous cultivators of science, keeping before their minds a noble ideal of a university, and doing their best to make that ideal a reality; and, to me, they would necessarily typify the universities, did not the authoritative statements I have quoted compel me to believe that they are exceptional, and not representative men. Indeed, upon calm consideration, several circumstances lead me to think that the Rector of Lincoln College and the Commissioners cannot be far wrong.

I believe there can be no doubt that the foreigner who should wish to become acquainted with the scientific, or the literary, activity of modern England, would simply lose his time and his pains if he visited our universities with that object.

And, as for works of profound research on any subject, and, above all, in that classical lore for which the universities profess to sacrifice almost everything else, why, a third-rate, poverty-stricken German university turns out more produce of that kind in one year than our vast and wealthy foundations elaborate in ten.

Ask the man who is investigating any question, profoundly and thoroughly—be it historical, philosophical, philological, physical, literary, or theological; who is trying to make himself master of any abstract subject (except, perhaps, political economy and geology, both of which are intensely Anglican sciences), whether he is not compelled to read half a dozen times as many German as English books? And whether, of these English books, more than one in ten is the work of a fellow of a college, or a professor of an English university?

Is this from any lack of power in the English as compared with the German mind? The countrymen of Grote and of Mill, of Faraday, of Robert Brown, of Lyell, and

of Darwin, to go no further back than the contemporaries of men of middle age, can afford to smile at such a suggestion. England can show now, as she has been able to show in every generation since civilisation spread over the West, individual men who hold their own against the world, and keep alive the old tradition of her intellectual eminence.

But, in the majority of cases, these men are what they are in virtue of their native intellectual force, and of a strength of character which will not recognise impediments. They are not trained in the courts of the Temple of Science, but storm the walls of that edifice in all sorts of irregular ways, and with much loss of time and power, in order to obtain their legitimate positions.

Our universities not only do not encourage such men; do not offer them positions, in which it should be their highest duty to do, thoroughly, that which they are most capable of doing; but, as far as possible, university training shuts out of the minds of those among them, who are subjected to it, the prospect that there is anything in the world for which they are specially fitted. Imagine the success of the attempt to still the intellectual hunger of any of the men I have mentioned, by putting before him, as the object of existence, the successful mimicry of the measure of a Greek song, or the roll of Ciceronian prose! Imagine how much success would be likely to attend the attempt to persuade such men that the education which leads to perfection in such elegances is alone to be called culture; while the facts of history, the process of thought, the conditions of moral and social existence, and the laws of physical nature are left to be dealt with as they may by outside barbarians!

It is not thus that the German universities, from being beneath notice a century ago, have become what they are

now—the most intensely cultivated and the most productive intellectual corporations the world has ever seen.

The student who repairs to them sees in the list of classes and of professors a fair picture of the world of knowledge. Whatever he needs to know there is some one ready to teach him, some one competent to discipline him in the way of learning; whatever his special bent, let him but be able and diligent, and in due time he shall find distinction and a career. Among his professors, he sees men whose names are known and revered throughout the civilised world; and their living example infects him with a noble ambition, and a love for the spirit of work.

The Germans dominate the intellectual world by virtue of the same simple secret as that which made Napoleon the master of old Europe. They have declared *la carrière ouverte aux talents*, and every Bursch marches with a professor's gown in his knapsack. Let him become a great scholar, or man of science, and ministers will compete for his services. In Germany they do not leave the chance of his holding the office he would render illustrious to the tender mercies of a hot canvass, and the final wisdom of a mob of country parsons.

In short, in Germany, the universities are exactly what the Rector of Lincoln and the Commissioners tell us the English universities are not; that is to say, corporations "of learned men devoting their lives to the cultivation of science, and the direction of academical education." They are not "boarding schools for youths," nor clerical seminaries; but institutions for the higher culture of men, in which the theological faculty is of no more importance or prominence than the rest; and which are truly "universities," since they strive to represent and embody the totality of human knowledge, and to find room for all forms of intellectual activity.

May zealous and clear-headed reformers like Mr. Pattison succeed in their noble endeavours to shape our universities towards some such ideal as this, without losing what is valuable and distinctive in their social tone! But until they have succeeded, a liberal education will be no more obtainable in our Oxford and Cambridge Universities than in our public schools.

If I am justified in my conception of the ideal of a liberal education, and if what I have said about the existing educational institutions of the country is also true, it is clear that the two have no sort of relation to one another; that the best of our schools and the most complete of our university trainings give but a narrow, one-sided, and essentially illiberal education—while the worst give what is really next to no education at all. The South London Working-Men's College could not copy any of these institutions if it would; I am bold enough to express the conviction that it ought not if it could.

For what is wanted is the reality and not the mere name of a liberal education; and this College must steadily set before itself the ambition to be able to give that education sooner or later. At present we are but beginning, sharpening our educational tools, as it were, and, except a modicum of physical science, we are not able to offer much more than is to be found in an ordinary school.

Moral and social science—one of the greatest and most fruitful of our future classes, I hope—at present lacks only one thing in our programme, and that is a teacher. A considerable want, no doubt; but it must be recollected that it is much better to want a teacher than to want the desire to learn.

Further, we need what, for want of a better name, I must call Physical Geography. What I mean is that which the Germans call *Erdkunde*. It is a description of the

earth, of its place and relation to other bodies; of its general structure, and of its great features—winds, tides, mountains, plains: of the chief forms of the vegetable and animal worlds, of the varieties of man. It is the peg upon which the greatest quantity of useful and entertaining scientific information can be suspended.

Literature is not upon the College programme; but I hope some day to see it there. For literature is the greatest of all sources of refined pleasure, and one of the great uses of a liberal education is to enable us to enjoy that pleasure. There is scope enough for the purposes of liberal education in the study of the rich treasures of our own language alone. All that is needed is direction, and the cultivation of a refined taste by attention to sound criticism. But there is no reason why French and German should not be mastered sufficiently to read what is worth reading in those languages with pleasure and with profit.

And finally, by and by, we must have History; treated not as a succession of battles and dynasties; not as a series of biographies; not as evidence that Providence has always been on the side of either Whigs or Tories; but as the development of man in times past, and in other conditions than our own.

But, as it is one of the principles of our College to be self-supporting, the public must lead, and we must follow, in these matters. If my hearers take to heart what I have said about liberal education, they will desire these things, and I doubt not we shall be able to supply them. But we must wait till the demand is made.

V

ON A PIECE OF CHALK

[1868]

[A lecture delivered to working men during the meeting of the British Association at Norwich, 1868. It is "a perfect example of the handling of a common and trivial subject so as to make it a window into the Infinite." It marks the maturing of Huxley's style "into that mastery of clear expression for which he deliberately laboured, the saying exactly what he meant, neither too much nor too little, without confusion and without obscurity," says his son.

This is a fine bit of argumentative writing. Its analysis will create power to follow logical development of a single thought for a definite purpose. The introduction should be studied in its relation to the main argument, the divisions of the essay should be clearly stated, and the importance of the subject matter should be dwelt upon. The purpose of the address is to establish by direct and indirect evidence the fragment of the history of the globe which is written in chalk, in a word to make the chalk tell its own story. Huxley carries out his purpose by proving the following three propositions:

1. That chalk is the dried mud of an ancient sea.
2. That the chalk sea is very ancient.
3. That the earth, from the time of the chalk to the present day, has been the theatre of a series of changes as vast in their amount as they were slow in their progress.

Careful briefs should be drawn of these three propositions and an analysis made of the inference that necessarily grows out of their establishment. A study of the kinds of evidence Huxley produces in support of his contentions would profit the student.

A parallelism may be drawn between the thought expressed in the following passage:

"I weigh my words well when I assert, that the man who should know the true history of the bit of chalk which every carpenter carries about in his breeches pocket, though ignorant of all other history, is likely, if he will think his knowledge out to its ultimate results, to have a truer, and therefore a better, conception of this wonderful universe, and of man's relation to it, than the most learned student who is deep-read in the records of humanity and ignorant of those of Nature," and Tennyson's well-known lines:

> "Flower in the crannied wall,
> I pluck you out of the crannies,
> I hold you here, root and all, in my hand,
> Little flower—but *if* I could understand
> What you are, root and all, and all in all,
> I should know what God and man is."

This essay offers a good opportunity for the study of Huxley's simplicity, directness, and concreteness of style. A study of the topic sentences, transitions, and summaries is also suggested.]

If a well were sunk at our feet in the midst of the city of Norwich, the diggers would very soon find themselves at work in that white substance almost too soft to be called rock, with which we are all familiar as "chalk."

Not only here, but over the whole county of Norfolk, the well-sinker might carry his shaft down many hundred feet without coming to the end of the chalk; and, on the sea-coast, where the waves have pared away the face of the

land which breasts them, the scarped faces of the high cliffs are often wholly formed of the same material. Northward, the chalk may be followed as far as Yorkshire; on the south coast it appears abruptly in the picturesque western bays of Dorset, and breaks into the Needles of the Isle of Wight; while on the shores of Kent it supplies that long line of white cliffs to which England owes her name of Albion.

Were the thin soil which covers it all washed away, a curved band of white chalk, here broader, and there narrower, might be followed diagonally across England from Lulworth in Dorset, to Flamborough Head in Yorkshire —a distance of over 280 miles as the crow flies. From this band to the North Sea, on the east, and the Channel, on the south, the chalk is largely hidden by other deposits; but, except in the Weald of Kent and Sussex, it enters into the very foundation of all the south-eastern counties.

Attaining, as it does in some places, a thickness of more than a thousand feet, the English chalk must be admitted to be a mass of considerable magnitude. Nevertheless, it covers but an insignificant portion of the whole area occupied by the chalk formation of the globe, much of which has the same general characters as ours, and is found in detached patches, some less, and others more extensive, than the English. Chalk occurs in north-west Ireland; it stretches over a large part of France—the chalk which underlies Paris being, in fact, a continuation of that of the London basin; it runs through Denmark and Central Europe, and extends southward to North Africa; while eastward, it appears in the Crimea and in Syria, and may be traced as far as the shores of the Sea of Aral, in Central Asia. If all the points at which true chalk occurs were circumscribed, they would lie within an irregular oval about 3,000 miles in long diameter—the area of which

would be as great as that of Europe, and would many times exceed that of the largest existing inland sea—the Mediterranean.

Thus the chalk is no unimportant element in the masonry of the earth's crust, and it impresses a peculiar stamp, varying with the conditions to which it is exposed, on the scenery of the districts in which it occurs. The undulating downs and rounded coombs, covered with sweet-grassed turf, of our inland chalk country, have a peacefully domestic and mutton-suggesting prettiness, but can hardly be called either grand or beautiful. But on our southern coasts, the wall-sided cliffs, many hundred feet high, with vast needles and pinnacles standing out in the sea, sharp and solitary enough to serve as perches for the wary cormorant, confer a wonderful beauty and grandeur upon the chalk headlands. And, in the East, chalk has its share in the formation of some of the most venerable of mountain ranges, such as the Lebanon.

What is this wide-spread component of the surface of the earth? and whence did it come?

You may think this no very hopeful inquiry. You may not unnaturally suppose that the attempt to solve such problems as these can lead to no result, save that of entangling the inquirer in vague speculations, incapable of refutation and of verification. If such were really the case, I should have selected some other subject than a "piece of chalk" for my discourse. But, in truth, after much deliberation, I have been unable to think of any topic which would so well enable me to lead you to see how solid is the foundation upon which some of the most startling conclusions of physical science rest.

A great chapter of the history of the world is written in the chalk. Few passages in the history of man can be

supported by such an overwhelming mass of direct and indirect evidence as that which testifies to the truth of the fragment of the history of the globe, which I hope to enable you to read, with your own eyes, to-night. Let me add, that few chapters of human history have a more profound significance for ourselves. I weigh my words well when I assert, that the man who should know the true history of the bit of chalk which every carpenter carries about in his breeches-pocket, though ignorant of all other history, is likely, if he will think his knowledge out to its ultimate results, to have a truer, and therefore a better, conception of this wonderful universe, and of man's relation to it, than the most learned student who is deep-read in the records of humanity and ignorant of those of Nature.

The language of the chalk is not hard to learn, not nearly so hard as Latin, if you only want to get at the broad features of the story it has to tell; and I propose that we now set to work to spell that story out together.

We all know that if we "burn" chalk the result is quicklime. Chalk, in fact, is a compound of carbonic acid gas, and lime, and when you make it very hot the carbonic acid flies away and the lime is left. By this method of procedure we see the lime, but we do not see the carbonic acid. If, on the other hand, you were to powder a little chalk and drop it into a good deal of strong vinegar, there would be a great bubbling and fizzing, and, finally, a clear liquid, in which no sign of chalk would appear. Here you see the carbonic acid in bubbles; the lime dissolved in the vinegar, vanishes from sight. There are a great many other ways of showing that chalk is essentially nothing but carbonic acid and quicklime. Chemists enunciate the result of all the experiments which prove this, by stating that chalk is almost wholly composed of "carbonate of lime."

It is desirable for us to start from the knowledge of this

fact, though it may not seem to help us very far towards what we seek. For carbonate of lime is a widely-spread substance, and is met with under very various conditions. All sorts of limestones are composed of more or less pure carbonate of lime. The crust which is often deposited by waters which have drained through limestone rocks, in the form of what are called stalagmites and stalactites, is carbonate of lime. Or, to take a more familiar example, the fur on the inside of a tea-kettle is carbonate of lime, and, for anything chemistry tells us to the contrary, the chalk might be a kind of gigantic fur upon the bottom of the earth-kettle, which is kept pretty hot below.

Let us try another method of making the chalk tell us its own history. To the unassisted eye chalk looks simply like a very loose and open kind of stone. But it is possible to grind a slice of chalk down so thin that you can see through it—until it is thin enough, in fact, to be examined with any magnifying power that may be thought desirable. A thin slice of the fur of a kettle might be made in the same way. If it were examined microscopically, it would show itself to be a more or less distinctly laminated mineral substance, and nothing more.

But the slice of chalk presents a totally different appearance when placed under the microscope. The general mass of it is made up of very minute granules; but, imbedded in this matrix, are innumerable bodies, some smaller and some larger, but, on a rough average, not more than a hundredth of an inch in diameter, having a well-defined shape and structure. A cubic inch of some specimens of chalk may contain hundreds of thousands of these bodies, compacted together with incalculable millions of the granules.

The examination of a transparent slice gives a good notion of the manner in which the components of the chalk are

arranged, and of their relative proportions. But, by rubbing up some chalk with a brush in water and then pouring off the milky fluid, so as to obtain sediments of different degrees of fineness, the granules and the minute rounded bodies may be pretty well separated from one another, and submitted to microscopic examination, either as opaque or as transparent objects. By combining the views obtained in these various methods, each of the rounded bodies may be proved to be a beautifully-constructed calcareous fabric, made up of a number of chambers, communicating freely with one another. The chambered bodies are of various forms. One of the commonest is something like a badly-grown raspberry, being formed of a number of nearly globular chambers of different sizes congregated together. It is called *Globigerina*, and some specimens of chalk consist of little else than *Globigerinæ* and granules. Let us fix our attention upon the *Globigerina*. It is the spoor of the game we are tracking. If we can learn what it is and what are the conditions of its existence, we shall see our way to the origin and past history of the chalk.

A suggestion which may naturally enough present itself is, that these curious bodies are the result of some process of aggregation which has taken place in the carbonate of lime; that, just as in winter, the rime on our windows simulates the most delicate and elegantly arborescent foliage —proving that the mere mineral water may, under certain conditions, assume the outward form of organic bodies— so this mineral substance, carbonate of lime, hidden away in the bowels of the earth, has taken the shape of these chambered bodies. I am not raising a merely fanciful and unreal objection. Very learned men, in former days, have even entertained the notion that all the formed things found in rocks are of this nature; and if no such conception is at present held to be admissible, it is because long and

varied experience has now shown that mineral matter never does assume the form and structure we find in fossils. If any one were to try to persuade you that an oyster-shell (which is also chiefly composed of carbonate of lime) had crystallized out of sea-water, I suppose you would laugh at the absurdity. Your laughter would be justified by the fact that all experience tends to show that oyster-shells are formed by the agency of oysters, and in no other way. And if there were no better reasons, we should be justified, on like grounds, in believing that *Globigerina* is not the product of anything but vital activity.

Happily, however, better evidence in proof of the organic nature of the *Globigerinæ* than that of analogy is forthcoming. It so happens that calcareous skeletons, exactly similar to the *Globigerinæ* of the chalk, are being formed, at the present moment, by minute living creatures, which flourish in multitudes, literally more numerous than the sands of the sea-shore, over a large extent of that part of the earth's surface which is covered by the ocean.

The history of the discovery of these living *Globigerinæ*, and of the part which they play in rock building, is singular enough. It is a discovery which, like others of no less scientific importance, has arisen, incidentally, out of work devoted to very different and exceedingly practical interests. When men first took to the sea, they speedily learned to look out for shoals and rocks; and the more the burthen of their ships increased, the more imperatively necessary it became for sailors to ascertain with precision the depth of the waters they traversed. Out of this necessity grew the use of the lead and sounding line; and, ultimately, marine-surveying, which is the recording of the form of coasts and of the depth of the sea, as ascertained by the sounding-lead, upon charts.

At the same time, it became desirable to ascertain and to

indicate the nature of the sea-bottom, since this circumstance greatly affects its goodness as holding ground for anchors. Some ingenious tar, whose name deserves a better fate than the oblivion into which it has fallen, attained this object by "arming" the bottom of the lead with a lump of grease, to which more or less of the sand or mud, or broken shells, as the case might be, adhered, and was brought to the surface. But, however well adapted such an apparatus might be for rough nautical purposes, scientific accuracy could not be expected from the armed lead, and to remedy its defects (especially when applied to sounding in great depths) Lieut. Brooke, of the American Navy, some years ago invented a most ingenious machine, by which a considerable portion of the superficial layer of the sea-bottom can be scooped out and brought up from any depth to which the lead descends. In 1853, Lieut. Brooke obtained mud from the bottom of the North Atlantic, between Newfoundland and the Azores, at a depth of more than 10,000 feet, or two miles, by the help of this sounding apparatus. The specimens were sent for examination to Ehrenberg of Berlin, and to Bailey of West Point, and those able microscopists found that this deep-sea mud was almost entirely composed of the skeletons of living organisms—the greater proportion of these being just like the *Globigerinæ* already known to occur in the chalk.

Thus far, the work had been carried on simply in the interests of science, but Lieut. Brooke's method of sounding acquired a high commercial value, when the enterprise of laying down the telegraph-cable between this country and the United States was undertaken. For it became a matter of immense importance to know, not only the depth of the sea over the whole line along which the cable was to be laid, but the exact nature of the bottom, so as to guard against chances of cutting or fraying the strands of that costly

rope. The Admiralty consequently ordered Captain Dayman, an old friend and shipmate of mine, to ascertain the depth over the whole line of the cable, and to bring back specimens of the bottom. In former days, such a command as this might have sounded very much like one of the impossible things which the young Prince in the Fairy Tales is ordered to do before he can obtain the hand of the Princess. However, in the months of June and July, 1857, my friend performed the task assigned to him with great expedition and precision, without, so far as I know, having met with any reward of that kind. The specimens of Atlantic mud which he procured were sent to me to be examined and reported upon.[1]

The result of all these operations is, that we know the contours and the nature of the surface-soil covered by the North Atlantic for a distance of 1,700 miles from east to west, as well as we know that of any part of the dry land. It is a prodigious plain—one of the widest and most even plains in the world. If the sea were drained off, you might drive a wagon all the way from Valentia, on the west coast of Ireland, to Trinity Bay, in Newfoundland. And, except upon one sharp incline about 200 miles from Valentia, I am not quite sure that it would even be necessary to put the skid on, so gentle are the ascents and descents upon that long route. From Valentia the road would lie down-hill for about 200 miles to the point at which the bottom is now covered by 1,700 fathoms of sea-water. Then would come the central plain, more than a thousand miles

[1] See Appendix to Captain Dayman's *Deep-sea Soundings in the North Atlantic Ocean between Ireland and Newfoundland, made in H.M.S. "Cyclops."* Published by order of the Lords Commissioners of the Admiralty, 1858. They have since formed the subject of an elaborate Memoir by Messrs. Parker and Jones, published in the *Philosophical Transactions* for 1865.

wide, the inequalities of the surface of which would be hardly perceptible, though the depth of water upon it now varies from 10,000 to 15,000 feet; and there are places in which Mont Blanc might be sunk without showing its peak above water. Beyond this, the ascent on the American side commences, and gradually leads, for about 300 miles, to the Newfoundland shore.

Almost the whole of the bottom of this central plain (which extends for many hundred miles in a north and south direction) is covered by a fine mud, which, when brought to the surface, dries into a greyish white friable substance. You can write with this on a blackboard, if you are so inclined; and, to the eye, it is quite like very soft, greyish chalk. Examined chemically, it proves to be composed almost wholly of carbonate of lime; and if you make a section of it, in the same way as that of the piece of chalk was made, and view it with the microscope, it presents innumerable *Globigerinæ* embedded in a granular matrix. Thus this deep-sea mud is substantially chalk. I say substantially, because there are a good many minor differences; but as these have no bearing on the question immediately before us—which is the nature of the *Globigerinæ* of the chalk—it is unnecessary to speak of them.

Globigerinæ of every size, from the smallest to the largest, are associated together in the Atlantic mud, and the chambers of many are filled by a soft animal matter. This soft substance is, in fact, the remains of the creature to which the *Globigerina* shell, or rather skeleton, owes its existence—and which is an animal of the simplest imaginable description. It is, in fact, a mere particle of living jelly, without defined parts of any kind—without a mouth, nerves, muscles, or distinct organs, and only manifesting its vitality to ordinary observation by thrusting out and retracting from all parts of its surface, long filamentous

processes, which serve for arms and legs. Yet this amorphous particle, devoid of everything which, in the higher animals, we call organs, is capable of feeding, growing, and multiplying; of separating from the ocean the small proportion of carbonate of lime which is dissolved in sea-water; and of building up that substance into a skeleton for itself, according to a pattern which can be imitated by no other known agency.

The notion that animals can live and flourish in the sea, at the vast depths from which apparently living *Globigerinæ* have been brought up, does not agree very well with our usual conceptions respecting the conditions of animal life; and it is not so absolutely impossible as it might at first sight appear to be, that the *Globigerinæ* of the Atlantic sea-bottom do not live and die where they are found.

As I have mentioned, the soundings from the great Atlantic plain are almost entirely made up of *Globigerinæ*, with the granules which have been mentioned, and some few other calcareous shells; but a small percentage of the chalky mud—perhaps at most some five per cent. of it—is of a different nature, and consists of shells and skeletons composed of silex, or pure flint. These silicious bodies belong partly to the lowly vegetable organisms which are called *Diatomaceæ*, and partly to the minute, and extremely simple, animals, termed *Radiolaria*. It is quite certain that these creatures do not live at the bottom of the ocean, but at its surface—where they may be obtained in prodigious numbers by the use of a properly constructed net. Hence it follows that these silicious organisms, though they are not heavier than the lightest dust, must have fallen, in some cases, through fifteen thousand feet of water, before they reached their final resting-place on the ocean floor. And considering how large a surface these bodies expose in proportion to their weight, it is probable that they occupy

a great length of time in making their burial journey from the surface of the Atlantic to the bottom.

But if the *Radiolaria* and Diatoms are thus rained upon the bottom of the sea, from the superficial layer of its waters in which they pass their lives, it is obviously possible that the *Globigerinæ* may be similarly derived; and if they were so, it would be much more easy to understand how they obtain their supply of food than it is at present. Nevertheless, the positive and negative evidence all points the other way. The skeletons of the full-grown, deep-sea *Globigerinæ* are so remarkably solid and heavy in proportion to their surface as to seem little fitted for floating; and, as a matter of fact, they are not to be found along with the Diatoms and *Radiolaria* in the uppermost stratum of the open ocean. It has been observed, again, that the abundance of *Globigerinæ,* in proportion to other organisms, of like kind, increases with the depth of the sea; and that deep-water *Globigerinæ* are larger than those which live in shallower parts of the sea; and such facts negative the supposition that these organisms have been swept by currents from the shallows into the deeps of the Atlantic. It therefore seems to be hardly doubtful that these wonderful creatures live and die at the depths in which they are found.[1]

However, the important points for us are, that the living *Globigerinæ* are exclusively marine animals, the skeletons

[1] During the cruise of H.M.S. *Bulldog*, commanded by Sir Leopold M'Clintock, in 1860, living star-fish were brought up, clinging to the lowest part of the sounding-line, from a depth of 1,260 fathoms, midway between Cape Farewell, in Greenland, and the Rockall banks. Dr. Wallich ascertained that the sea bottom at this point consisted of the ordinary *Globigerina* ooze, and that the stomachs of the star-fishes were full of *Globigerinæ*. This discovery removes all objections to the existence of living

of which abound at the bottom of deep seas; and that there is not a shadow of reason for believing that the habits of the *Globigerinæ* of the chalk differed from those of the existing species. But if this be true, there is no escaping the conclusion that the chalk itself is the dried mud of an ancient deep sea.

In working over the soundings collected by Captain Dayman, I was surprised to find that many of what I have called the "granules" of that mud were not, as one might have been tempted to think at first, the mere powder and waste of *Globigerinæ*, but that they had a definite form and size. I termed these bodies "*coccoliths*," and doubted their organic nature. Dr. Wallich verified my observation, and added the interesting discovery that, not unfrequently, bodies similar to these "coccoliths" were aggregated together into spheroids, which he termed "*coccospheres*." So far as we knew, these bodies, the nature of which is extremely puzzling and problematical, were peculiar to the Atlantic soundings. But, a few years ago, Mr. Sorby, in making a careful examination of the chalk by means of thin sections and otherwise, observed, as Ehrenberg had done before him, that much of its granular basis possesses a definite form. Comparing these formed particles with those in the Atlantic soundings, he found the two to be identical; and thus proved that the chalk, like the soundings, contains these mysterious coccoliths and coccospheres. Here was a further and most interesting confirmation, from internal evidence, of the essential identity of the chalk with modern deep-sea mud. *Globigerinæ*, coccoliths,

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Globigerinæ at great depths, which are based upon the supposed difficulty of maintaining animal life under such conditions; and it throws the burden of proof upon those who object to the supposition that the *Globigerinæ* live and die where they are found.

and coccospheres are found as the chief constituents of both, and testify to the general similarity of the conditions under which both have been formed.[1]

The evidence furnished by the hewing, facing, and superposition of the stones of the Pyramids, that these structures were built by men, has no greater weight than the evidence that the chalk was built by *Globigerinæ;* and the belief that those ancient pyramid-builders were terrestrial and air-breathing creatures like ourselves, is not better based than the conviction that the chalk-makers lived in the sea. But as our belief in the building of the Pyramids by men is not only grounded on the internal evidence afforded by these structures, but gathers strength from multitudinous collateral proofs, and is clinched by the total absence of any reason for a contrary belief; so the evidence drawn from the *Globigerinæ* that the chalk is an ancient sea-bottom, is fortified by innumerable independent lines of evidence; and our belief in the truth of the conclusion to which all positive testimony tends, receives the like negative justification from the fact that no other hypothesis has a shadow of foundation.

It may be worth while briefly to consider a few of these collateral proofs that the chalk was deposited at the bottom of the sea. The great mass of the chalk is composed, as we have seen, of the skeletons of *Globigerinæ,* and other simple organisms, imbedded in granular matter. Here and there, however, this hardened mud of the ancient sea reveals the remains of higher animals which have lived and died, and left their hard parts in the mud, just as the oysters die

[1] I have recently traced out the development of the "coccoliths" from a diameter of $\frac{1}{7000}$th of an inch up to their largest size (which is about $\frac{1}{1600}$th), and no longer doubt that they are produced by independent organisms, which, like the *Globigerinæ,* live and die at the bottom of the sea.

and leave their shells behind them, in the mud of the present seas.

There are, at the present day, certain groups of animals which are never found in fresh waters, being unable to live anywhere but in the sea. Such are the corals; those corallines which are called *Polyzoa;* those creatures which fabricate the lamp-shells, and are called *Brachiopoda;* the pearly *Nautilus,* and all animals allied to it; and all the forms of sea-urchins and star-fishes. Not only are all these creatures confined to salt water at the present day; but, so far as our records of the past go, the conditions of their existence have been the same: hence, their occurrence in any deposit is as strong evidence as can be obtained, that that deposit was formed in the sea. Now the remains of animals of all kinds which have been enumerated, occur in the chalk, in greater or less abundance; while not one of those forms of shell-fish which are characteristic of fresh water has yet been observed in it.

When we consider that the remains of more than three thousand distinct species of aquatic animals have been discovered among the fossils of the chalk, that the great majority of them are of such forms as are now met with only in the sea, and that there is no reason to believe that any one of them inhabited fresh water—the collateral evidence that the chalk represents an ancient sea-bottom acquires as great force as the proof derived from the nature of the chalk itself. I think you will now allow that I did not overstate my case when I asserted that we have as strong grounds for believing that all the vast area of dry land, at present occupied by the chalk, was once at the bottom of the sea, as we have for any matter of history whatever; while there is no justification for any other belief.

No less certain it is that the time during which the countries we now call south-east England, France, Ger-

many, Poland, Russia, Egypt, Arabia, Syria, were more or less completely covered by a deep sea, was of considerable duration. We have already seen that the chalk is, in places, more than a thousand feet thick. I think you will agree with me, that it must have taken some time for the skeletons of animalcules of a hundredth of an inch in diameter to heap up such a mass as that. I have said that throughout the thickness of the chalk the remains of other animals are scattered. These remains are often in the most exquisite state of preservation. The valves of the shell-fishes are commonly adherent; the long spines of some of the sea-urchins, which would be detached by the smallest jar, often remain in their places. In a word, it is certain that these animals have lived and died when the place which they now occupy was the surface of as much of the chalk as had then been deposited; and that each has been covered up by the layer of *Globigerina* mud, upon which the creatures imbedded a little higher up have, in like manner, lived and died. But some of these remains prove the existence of reptiles of vast size in the chalk sea. These lived their time, and had their ancestors and descendants, which assuredly implies time, reptiles being of slow growth.

There is more curious evidence, again, that the process of covering up, or, in other words, the deposit of *Globigerina* skeletons, did not go on very fast. It is demonstrable that an animal of the cretaceous sea might die, that its skeleton might lie uncovered upon the sea-bottom long enough to lose all its outward coverings and appendages by putrefaction; and that, after this had happened, another animal might attach itself to the dead and naked skeleton, might grow to maturity, and might itself die before the calcareous mud had buried the whole.

Cases of this kind are admirably described by Sir Charles Lyell. He speaks of the frequency with which geologists

find in the chalk a fossilized sea-urchin, to which is attached the lower valve of a *Crania*. This is a kind of shell-fish, with a shell composed of two pieces, of which, as in the oyster, one is fixed and the other free.

"The upper valve is almost invariably wanting, though occasionally found in a perfect state of preservation in the white chalk at some distance. In this case, we see clearly that the sea-urchin first lived from youth to age, then died and lost its spines, which were carried away. Then the young *Crania* adhered to the bared shell, grew and perished in its turn; after which, the upper valve was separated from the lower, before the Echinus became enveloped in chalky mud." [1]

A specimen in the Museum of Practical Geology, in London, still further prolongs the period which must have elapsed between the death of the sea-urchin, and its burial by the *Globigerinæ*. For the outward face of the valve of a *Crania*, which is attached to a sea-urchin (*Micraster*), is itself overrun by an incrusting coralline, which spreads thence over more or less of the surface of the sea-urchin. It follows that, after the upper valve of the *Crania* fell off, the surface of the attached valve must have remained exposed long enough to allow of the growth of the whole coralline, since corallines do not live embedded in mud.

The progress of knowledge may, one day, enable us to deduce from such facts as these the maximum rate at which the chalk can have accumulated, and thus to arrive at the minimum duration of the chalk period. Suppose that the valve of the *Crania* upon which a coralline has fixed itself in the way just described, is so attached to the sea-urchin that no part of it is more than an inch above the face upon

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[1] *Elements of Geology*, by Sir Charles Lyell, Bart., F.R.S., p. 23.

which the sea-urchin rests. Then, as the coralline could not have fixed itself, if the *Crania* had been covered up with chalk mud, and could not have lived had itself been so covered, it follows, that an inch of chalk mud could not have accumulated within the time between the death and decay of the soft parts of the sea-urchin and the growth of the coralline to the full size which it has attained. If the decay of the soft parts of the sea-urchin; the attachment, growth to maturity, and decay of the *Crania;* and the subsequent attachment and growth of the coralline, took a year (which is a low estimate enough), the accumulation of the inch of chalk must have taken more than a year: and the deposit of a thousand feet of chalk must, consequently, have taken more than twelve thousand years.

The foundation of all this calculation is, of course, a knowledge of the length of time the *Crania* and the coralline needed to attain their full size; and, on this head, precise knowledge is at present wanting. But there are circumstances which tend to show, that nothing like an inch of chalk has accumulated during the life of a *Crania;* and, on any probable estimate of the length of that life, the chalk period must have had a much longer duration than that thus roughly assigned to it.

Thus, not only is it certain that the chalk is the mud of an ancient sea-bottom; but it is no less certain, that the chalk sea existed during an extremely long period, though we may not be prepared to give a precise estimate of the length of that period in years. The relative duration is clear, though the absolute duration may not be definable. The attempt to affix any precise date to the period at which the chalk sea began, or ended, its existence, is baffled by difficulties of the same kind. But the relative age of the cretaceous epoch may be determined with as great ease and certainty as the long duration of that epoch.

You will have heard of the interesting discoveries recently made, in various parts of Western Europe, of flint implements, obviously worked into shape by human hands, under circumstances which show conclusively that man is a very ancient denizen of these regions. It has been proved that the whole populations of Europe, whose existence has been revealed to us in this way, consisted of savages, such as the Esquimaux are now; that, in the country which is now France, they hunted the reindeer, and were familiar with the ways of the mammoth and the bison. The physical geography of France was in those days different from what it is now—the river Somme, for instance, having cut its bed a hundred feet deeper between that time and this; and, it is probable, that the climate was more like that of Canada or Siberia, than that of Western Europe.

The existence of these people is forgotten even in the traditions of the oldest historical nations. The name and fame of them had utterly vanished until a few years back; and the amount of physical change which has been effected since their day renders it more than probable that, venerable as are some of the historical nations, the workers of the chipped flints of Hoxne or of Amiens are to them, as they are to us, in point of antiquity. But, if we assign to these hoar relics of long-vanished generations of men the greatest age that can possibly be claimed for them, they are not older than the drift, or boulder clay, which, in comparison with the chalk, is but a very juvenile deposit. You need go no further than your own sea-board for evidence of this fact. At one of the most charming spots on the coast of Norfolk, Cromer, you will see the boulder clay forming a vast mass, which lies upon the chalk, and must consequently have come into existence after it. Huge boulders of chalk are, in fact, included in the clay, and have evidently been brought to the position they now occupy

by the same agency as that which has planted blocks of syenite from Norway side by side with them.

The chalk, then, is certainly older than the boulder clay. If you ask how much, I will again take you no further than the same spot upon your own coasts for evidence. I have spoken of the boulder clay and drift as resting upon the chalk. That is not strictly true. Interposed between the chalk and the drift is a comparatively insignificant layer, containing vegetable matter. But that layer tells a wonderful history. It is full of stumps of trees standing as they grew. Fir-trees are there with their cones, and hazel-bushes with their nuts; there stand the stools of oak and yew trees, beeches and alders. Hence this stratum is appropriately called the "forest-bed."

It is obvious that the chalk must have been upheaved and converted into dry land, before the timber trees could grow upon it. As the bolls of some of these trees are from two to three feet in diameter, it is no less clear that the dry land thus formed remained in the same condition for long ages. And not only do the remains of stately oaks and well-grown firs testify to the duration of this condition of things, but additional evidence to the same effect is afforded by the abundant remains of elephants, rhinoceroses, hippopotamuses, and other great wild beasts, which it has yielded to the zealous search of such men as the Rev. Mr. Gunn. When you look at such a collection as he has formed, and bethink you that these elephantine bones did veritably carry their owners about, and these great grinders crunch, in the dark woods of which the forest-bed is now the only trace, it is impossible not to feel that they are as good evidence of the lapse of time as the annual rings of the tree stumps.

Thus there is a writing upon the wall of cliffs at Cromer, and whoso runs may read it. It tells us, with an authority

which cannot be impeached, that the ancient sea-bed of the chalk sea was raised up, and remained dry land, until it was covered with forest, stocked with the great game the spoils of which have rejoiced your geologists. How long it remained in that condition cannot be said; but "the whirligig of time brought its revenges" in those days as in these. That dry land, with the bones and teeth of generations of long-lived elephants, hidden away among the gnarled roots and dry leaves of its ancient trees, sank gradually to the bottom of the icy sea, which covered it with huge masses of drift and boulder clay. Sea-beasts, such as the walrus, now restricted to the extreme north, paddled about where birds had twittered among the topmost twigs of the fir-trees. How long this state of things endured we know not, but at length it came to an end. The upheaved glacial mud hardened into the soil of modern Norfolk. Forests grew once more, the wolf and the beaver replaced the reindeer and the elephant; and at length what we call the history of England dawned.

Thus you have, within the limits of your own county, proof that the chalk can justly claim a very much greater antiquity than even the oldest physical traces of mankind. But we may go further and demonstrate, by evidence of the same authority as that which testifies to the existence of the father of men, that the chalk is vastly older than Adam himself. The Book of Genesis informs us that Adam, immediately upon his creation, and before the appearance of Eve, was placed in the Garden of Eden. The problem of the geographical position of Eden has greatly vexed the spirits of the learned in such matters, but there is one point respecting which, so far as I know, no commentator has ever raised a doubt. This is, that of the four rivers which are said to run out of it, Euphrates and Hiddekel are identical with the rivers now known by the names of Eu-

phrates and Tigris. But the whole country in which these mighty rivers take their origin, and through which they run, is composed of rocks which are either of the same age as the chalk, or of later date. So that the chalk must not only have been formed, but, after its formation, the time required for the deposit of these later rocks, and for their upheaval into dry land, must have elapsed, before the smallest brook which feeds the swift stream of "the great river, the river of Babylon," began to flow.

Thus, evidence which cannot be rebutted, and which need not be strengthened, though if time permitted I might indefinitely increase its quantity, compels you to believe that the earth, from the time of the chalk to the present day, has been the theatre of a series of changes as vast in their amount, as they were slow in their progress. The area on which we stand has been first sea and then land, for at least four alternations; and has remained in each of these conditions for a period of great length.

Nor have these wonderful metamorphoses of sea into land, and of land into sea, been confined to one corner of England. During the chalk period, or "cretaceous epoch," not one of the present great physical features of the globe was in existence. Our great mountain ranges, Pyrenees, Alps, Himalayas, Andes, have all been upheaved since the chalk was deposited, and the cretaceous sea flowed over the sites of Sinai and Ararat. All this is certain, because rocks of cretaceous, or still later, date have shared in the elevatory movements which gave rise to these mountain chains; and may be found perched up, in some cases, many thousand feet high upon their flanks. And evidence of equal cogency demonstrates that, though, in Norfolk, the forest-bed rests directly upon the chalk, yet it does so, not because the period at which the forest grew immediately followed

that at which the chalk was formed, but because an immense lapse of time, represented elsewhere by thousands of feet of rock, is not indicated at Cromer.

I must ask you to believe that there is no less conclusive proof that a still more prolonged succession of similar changes occurred, before the chalk was deposited. Nor have we any reason to think that the first term in the series of these changes is known. The oldest sea-beds preserved to us are sands, and mud, and pebbles, the wear and tear of rocks which were formed in still older oceans.

But, great as is the magnitude of these physical changes of the world, they have been accompanied by a no less striking series of modifications in its living inhabitants. All the great classes of animals, beasts of the field, fowls of the air, creeping things, and things which dwell in the waters, flourished upon the globe long ages before the chalk was deposited. Very few, however, if any, of these ancient forms of animal life were identical with those which now live. Certainly not one of the higher animals was of the same species as any of those now in existence. The beasts of the field, in the days before the chalk, were not our beasts of the field, nor the fowls of the air such as those which the eye of man has seen flying, unless his antiquity dates infinitely further back than we at present surmise. If we could be carried back into those times, we should be as one suddenly set down in Australia before it was colonized. We should see mammals, birds, reptiles, fishes, insects, snails, and the like, clearly recognizable as such, and yet not one of them would be just the same as those with which we are familiar, and many would be extremely different.

From that time to the present, the population of the world has undergone slow and gradual, but incessant, changes. There has been no grand catastrophe—no de-

stroyer has swept away the forms of life of one period, and replaced them by a totally new creation: but one species has vanished and another has taken its place; creatures of one type of structure have diminished, those of another have increased, as time has passed on. And thus, while the differences between the living creatures of the time before the chalk and those of the present day appear startling, if placed side by side, we are led from one to the other by the most gradual progress, if we follow the course of Nature through the whole series of those relics of her operations which she has left behind. It is by the population of the chalk sea that the ancient and the modern inhabitants of the world are most completely connected. The groups which are dying out flourish, side by side, with the groups which are now the dominant forms of life. Thus the chalk contains remains of those strange flying and swimming reptiles, the pterodactyl, the ichthyosaurus, and the plesiosaurus, which are found in no later deposits, but abounded in preceding ages. The chambered shells called ammonites and belemnites, which are so characteristic of the period preceding the cretaceous, in like manner die with it.

But, amongst these fading remainders of a previous state of things, are some very modern forms of life, looking like Yankee pedlars among a tribe of Red Indians. Crocodiles of modern type appear; bony fishes, many of them very similar to existing species, almost supplant the forms of fish which predominate in more ancient seas; and many kinds of living shell-fish first become known to us in the chalk. The vegetation acquires a modern aspect. A few living animals are not even distinguishable as species, from those which existed at that remote epoch. The *Globigerina* of the present day, for example, is not different specifically from that of the chalk; and the same may be said of many

other *Foraminifera*. I think it probable that critical and unprejudiced examination will show that more than one species of much higher animals have had a similar longevity; but the only example which I can at present give confidently is the snake's-head lamp-shell (*Terebratulina caput serpentis*), which lives in our English seas and abounded (as *Terebratulina striata* of authors) in the chalk.

The longest line of human ancestry must hide its diminished head before the pedigree of this insignificant shellfish. We Englishmen are proud to have an ancestor who was present at the Battle of Hastings. The ancestors of *Terebratulina caput serpentis* may have been present at a battle of *Ichthyosauria* in that part of the sea which, when the chalk was forming, flowed over the site of Hastings. When all around has changed, this *Terebratulina* has peacefully propagated its species from generation to generation, and stands to this day, as a living testimony to the continuity of the present with the past history of the globe.

Up to this moment I have stated, so far as I know, nothing but well-authenticated facts, and the immediate conclusions which they force upon the mind. But the mind is so constituted that it does not willingly rest in facts and immediate causes, but seeks always after a knowledge of the remoter links in the chain of causation.

Taking the many changes of any given spot of the earth's surface, from sea to land and from land to sea, as an established fact, we cannot refrain from asking ourselves how these changes have occurred. And when we have explained them—as they must be explained—by the alternate slow movements of elevation and depression which have affected the crust of the earth, we go still further back, and ask, Why these movements?

I am not certain that any one can give you a satisfactory answer to that question. Assuredly I cannot. All that can be said, for certain, is, that such movements are part of the ordinary course of nature, inasmuch as they are going on at the present time. Direct proof may be given, that some parts of the land of the northern hemisphere are at this moment insensibly rising and others insensibly sinking; and there is indirect, but perfectly satisfactory, proof, that an enormous area now covered by the Pacific has been deepened thousands of feet, since the present inhabitants of that sea came into existence. Thus there is not a shadow of a reason for believing that the physical changes of the globe, in past times, have been effected by other than natural causes. Is there any more reason for believing that the concomitant modifications in the forms of the living inhabitants of the globe have been brought about in other ways?

Before attempting to answer this question, let us try to form a distinct mental picture of what has happened in some special case. The crocodiles are animals which, as a group, have a very vast antiquity. They abounded ages before the chalk was deposited; they throng the rivers in warm climates, at the present day. There is a difference in the form of the joints of the back-bone, and in some minor particulars, between the crocodiles of the present epoch and those which lived before the chalk; but, in the cretaceous epoch, as I have already mentioned, the crocodiles had assumed the modern type of structure. Notwithstanding this, the crocodiles of the chalk are not identically the same as those which lived in the times called "older tertiary," which succeeded the cretaceous epoch; and the crocodiles of the older tertiaries are not identical with those of the newer tertiaries, nor are these identical with existing forms. I leave open the question whether particular

species may have lived on from epoch to epoch. But each epoch has had its peculiar crocodiles; though all, since the chalk, have belonged to the modern type, and differ simply in their proportions, and in such structural particulars as are discernible only to trained eyes.

How is the existence of this long succession of different species of crocodiles to be accounted for? Only two suppositions seem to be open to us. Either each species of crocodile has been specially created, or it has arisen out of some pre-existing form by the operation of natural causes. Choose your hypothesis; I have chosen mine. I can find no warranty for believing in the distinct creation of a score of successive species of crocodiles in the course of countless ages of time. Science gives no countenance to such a wild fancy; nor can even the perverse ingenuity of a commentator pretend to discover this sense, in the simple words in which the writer of Genesis records the proceedings of the fifth and sixth days of the Creation.

On the other hand, I see no good reason for doubting the necessary alternative, that all these varied species have been evolved from pre-existing crocodilian forms, by the operation of causes as completely a part of the common order of nature as those which have effected the changes of the inorganic world. Few will venture to affirm that the reasoning which applies to crocodiles loses its force among other animals, or among plants. If one series of species has come into existence by the operation of natural causes, it seems folly to deny that all may have arisen in the same way.

A small beginning has led us to a great ending. If I were to put the bit of chalk with which we started into the hot but obscure flame of burning hydrogen, it would presently shine like the sun. It seems to me that this

physical metamorphosis is no false image of what has been the result of our subjecting it to a jet of fervent, though nowise brilliant, thought to-night. It has become luminous, and its clear rays, penetrating the abyss of the remote past, have brought within our ken some stages of the evolution of the earth. And in the shifting "without haste, but without rest" of the land and sea, as in the endless variation of the forms assumed by living beings, we have observed nothing but the natural product of the forces originally possessed by the substance of the universe.

VI

ON SCIENCE AND ART IN RELATION TO EDUCATION

[1882]

[This address was delivered before the members of the Liverpool Institution in 1882. Here Huxley brings an indictment against the so-called literary education, but makes a plea for what he considers real literary training. He enumerates the principal subjects of education and defends his choice.

After an introduction in which he summarizes the points he had made in a lecture on Scientific Education given in the same city fourteen years before, and in which he emphasizes the fact that he is not an advocate of a one-sided education, he comes to the main business of his talk, which is a discussion of the principal subjects of education. A detailed analysis of Huxley's choice should be made as to basis, classification, and relative value of subjects selected. It might be profitable to make a comparison between Huxley's idea of the right and wrong kind of literary training. Special attention is called to his appreciation of the worth of literature as a subject of education, and of the importance of teaching English composition. "I fancy we are almost the only nation in the world," he tells us, "who seem to think that composition comes by nature. The French attend to their own language, the Germans study theirs, but Englishmen do not seem to think it is worth their while."

A study of sentence and paragraph structure is also suggested.]

When a man is honoured by such a request as that which reached me from the authorities of your institution some time ago, I think the first thing that occurs to him is that which occurred to those who were bidden to the feast in the Gospel—to begin to make an excuse; and probably all the excuses suggested on that famous occasion crop up in his mind one after the other, including his "having married a wife," as reasons for not doing what he is asked to do. But, in my own case, and on this particular occasion, there were other difficulties of a sort peculiar to the time, and more or less personal to myself; because I felt that, if I came amongst you, I should be expected, and, indeed, morally compelled, to speak upon the subject of Scientific Education. And then there arose in my mind the recollection of a fact, which probably no one here but myself remembers; namely, that some fourteen years ago I was the guest of a citizen of yours, who bears the honoured name of Rathbone, at a very charming and pleasant dinner given by the Philomathic Society; and I there and then, and in this very city, made a speech upon the topic of Scientific Education. Under these circumstances, you see, one runs two dangers—the first, of repeating one's self, although I may fairly hope that everybody has forgotten the fact I have just now mentioned, except myself; and the second, and even greater difficulty, is the danger of saying something different from what one said before, because then, however forgotten your previous speech may be, somebody finds out its existence, and there goes on that process so hateful to members of Parliament, which may be denoted by the term "Hansardisation." Under these circumstances, I came to the conclusion that

the best thing I could do was to take the bull by the horns, and to "Hansardise" myself—to put before you, in the briefest possible way, the three or four propositions which I endeavoured to support on the occasion of the speech to which I have referred; and then to ask myself, supposing you were asking me, whether I had anything to retract, or to modify, in them, in virtue of the increased experience, and, let us charitably hope, the increased wisdom of an added fourteen years.

Now, the points to which I directed particular attention on that occasion were these: in the first place, that instruction in physical science supplies information of a character of especial value, both in a practical and a speculative point of view—information which cannot be obtained otherwise; and, in the second place, that, as educational discipline, it supplies, in a better form than any other study can supply, exercise in a special form of logic, and a peculiar method of testing the validity of our processes of inquiry. I said further, that, even at that time, a great and increasing attention was being paid to physical science in our schools and colleges, and that, most assuredly, such attention must go on growing and increasing, until education in these matters occupied a very much larger share of the time which is given to teaching and training, than had been the case heretofore. And I threw all the strength of argumentation of which I was possessed into the support of these propositions. But I venture to remind you, also, of some other words I used at that time, and which I ask permission to read to you. They were these: "There are other forms of culture besides physical science, and I should be profoundly sorry to see the fact forgotten, or even to observe a tendency to starve or cripple literary or æsthetic culture for the sake of science. Such a narrow view of the nature of education has nothing to do with

my firm conclusion that a complete and thorough scientific culture ought to be introduced into all schools."

I say I desire, in commenting upon these various points, and judging them as fairly as I can by the light of increased experience, to particularly emphasise this last, because I am told, although I assuredly do not know it of my own knowledge—though I think if the fact were so I ought to know it, being tolerably well acquainted with that which goes on in the scientific world, and which has gone on there for the last thirty years—that there is a kind of sect, or horde, of scientific Goths and Vandals, who think it would be proper and desirable to sweep away all other forms of culture and instruction, except those in physical science, and to make them the universal and exclusive, or, at any rate, the dominant training of the human mind of the future generation. This is not my view —I do not believe that it is anybody's view—but it is attributed to those who, like myself, advocate scientific education. I therefore dwell strongly upon the point, and I beg you to believe that the words I have just now read were by no means intended by me as a sop to the Cerberus of culture. I have not been in the habit of offering sops to any kind of Cerberus; but it was an expression of profound conviction on my own part—a conviction forced upon me not only by my mental constitution, but by the lessons of what is now becoming a somewhat long experience of varied conditions of life.

I am not about to trouble you with my autobiography; the omens are hardly favourable, at present, for work of that kind. But I should like if I may do so without appearing, what I earnestly desire not to be, egotistical—I should like to make it clear to you, that such notions as these, which are sometimes attributed to me, are, as I have said, inconsistent with my mental constitution, and still

more inconsistent with the upshot of the teaching of my experience. For I can certainly claim for myself that sort of mental temperament which can say that nothing human comes amiss to it. I have never yet met with any branch of human knowledge which I have found unattractive—which it would not have been pleasant to me to follow, so far as I could go; and I have yet to meet with any form of art in which it has not been possible for me to take as acute a pleasure as, I believe, it is possible for men to take.

And with respect to the circumstances of life, it so happens that it has been my fate to know many lands and many climates, and to be familiar, by personal experience, with almost every form of society, from the uncivilised savage of Papua and Australia and the civilised savages of the slums and dens of the poverty-stricken parts of great cities, to those who perhaps, are occasionally the somewhat over-civilised members of our upper ten thousand. And I have never found, in any of these conditions of life, a deficiency of something which was attractive. Savagery has its pleasures, I assure you, as well as civilisation, and I may even venture to confess—if you will not let a whisper of the matter get back to London, where I am known—I am even fain to confess, that sometimes in the din and throng of what is called "a brilliant reception" the vision crosses my mind of waking up from the soft plank which had afforded me satisfactory sleep during the hours of the night, in the bright dawn of a tropical morning, when my comrades were yet asleep, when every sound was hushed, except the little lap-lap of the ripples against the sides of the boat, and the distant twitter of the sea-bird on the reef. And when that vision crosses my mind, I am free to confess I desire to be back in the boat again. So that, if I share with those strange persons to

whose asserted, but still hypothetical existence I have referred, the want of appreciation of forms of culture other than the pursuit of physical science, all I can say is, that it is, in spite of my constitution, and in spite of my experience, that such should be my fate.

But now let me turn to another point, or rather to two other points, with which I propose to occupy myself. How far does the experience of the last fourteen years justify the estimate which I ventured to put forward of the value of scientific culture, and of the share—the increasing share —which it must take in ordinary education? Happily, in respect to that matter, you need not rely upon my testimony. In the last half-dozen numbers of the "Journal of Education," you will find a series of very interesting and remarkable papers, by gentlemen who are practically engaged in the business of education in our great public and other schools, telling us what is doing in these schools, and what is their experience of the results of scientific education there, so far as it has gone. I am not going to trouble you with an abstract of those papers which are well worth your study in their fulness and completeness, but I have copied out one remarkable passage, because it seems to me so entirely to bear out what I have formerly ventured to say about the value of science, both as to its subject-matter and as to the discipline which the learning of science involves. It is from a paper by Mr. Worthington—one of the masters at Clifton, the reputation of which school you know well, and at the head of which is an old friend of mine, the Rev. Mr. Wilson—to whom much credit is due for being one of the first, as I can say from my own knowledge, to take up this question and work it into practical shape. What Mr. Worthington says is this:

"It is not easy to exaggerate the importance of the information imparted by certain branches of science; it modi-

fies the whole criticism of life made in maturer years. The study has often, on a mass of boys, a certain influence which, I think, was hardly anticipated, and to which a good deal of value must be attached—an influence as much moral as intellectual, which is shown in the increased and increasing respect for precision of statement, and for that form of veracity which consists in the acknowledgment of difficulties. It produces a real effect to find that Nature cannot be imposed upon, and the attention given to experimental lectures, at first superficial and curious only, soon becomes minute, serious, and practical."

Ladies and gentlemen, I could not have chosen better words to express—in fact, I have, in other words, expressed the same conviction in former days—what the influence of scientific teaching, if properly carried out, must be.

But now comes the question of properly carrying it out, because, when I hear the value of school teaching in physical science disputed, my first impulse is to ask the disputer, "What have you known about it?" and he generally tells me some lamentable case of failure. Then I ask, "What are the circumstances of the case, and how was the teaching carried out?" I remember, some few years ago, hearing of the head master of a large school, who had expressed great dissatisfaction with the adoption of the teaching of physical science—and that after experiment. But the experiment consisted in this—in asking one of the junior masters in the school to get up science, in order to teach it; and the young gentleman went away for a year and got up science and taught it. Well, I have no doubt that the result was as disappointing as the headmaster said it was, and I have no doubt that it ought to have been as disappointing, and far more disappointing too; for, if this kind of instruction is to be of any good at all, if it is not to be less than no good, if it is to take

the place of that which is already of some good, then there are several points which must be attended to.

And the first of these is the proper selection of topics, the second is practical teaching, the third is practical teachers, and the fourth is sufficiency of time. If these four points are not carefully attended to by anybody who undertakes the teaching of physical science in schools, my advice to him is, to let it alone. I will not dwell at any length upon the first point, because there is a general consensus of opinion as to the nature of the topics which should be chosen. The second point—practical teaching—is one of great importance, because it requires more capital to set it agoing, demands more time, and, last, but by no means least, it requires much more personal exertion and trouble on the part of those professing to teach, than is the case with other kinds of instruction.

When I accepted the invitation to be here this evening, your secretary was good enough to send me the addresses which have been given by distinguished persons who have previously occupied this chair. I don't know whether he had a malicious desire to alarm me; but, however that may be, I read the addresses, and derived the greatest pleasure and profit from some of them, and from none more than from the one given by the great historian, Mr. Freeman, which delighted me most of all; and, if I had not been ashamed of plagiarising, and if I had not been sure of being found out, I should have been glad to have copied very much of what Mr. Freeman said, simply putting in the word science for history. There was one notable passage: "The difference between good and bad teaching mainly consists in this, whether the words used are really clothed with a meaning or not." And Mr. Freeman gives a remarkable example of this. He says, when a little girl was asked where Turkey was, she answered that it was in

the yard with the other fowls, and that showed she had a definite idea connected with the word Turkey, and was, so far, worthy of praise. I quite agree with that commendation; but what a curious thing it is that one should now find it necessary to urge that this is the be-all and end-all of scientific instruction—the *sine quâ non,* the absolutely necessary condition,—and yet that it was insisted upon more than two hundred years ago by one of the greatest men science ever possessed in this country, William Harvey. Harvey wrote, or at least published, only two small books, one of which is the well-known treatise on the circulation of the blood. The other, the "Exercitationes de Generatione," is less known, but not less remarkable. And not the least valuable part of it is the preface, in which there occurs this passage: "Those who, reading the words of authors, do not form sensible images of the things referred to, obtain no true ideas, but conceive false imaginations and inane phantasms." You see, William Harvey's words are just the same in substance as those of Mr. Freeman, only they happen to be rather more than two centuries older. So that what I am now saying has its application elsewhere than in science; but assuredly in science the condition of knowing, of your own knowledge, things which you talk about, is absolutely imperative.

I remember, in my youth, there were detestable books which ought to have been burned by the hands of the common hangman, for they contained questions and answers to be learned by heart, of this sort, "What is a horse? The horse is termed *Equus caballus;* belongs to the class Mammalia; order, Pachydermata; family, Solidungula." Was any human being wiser for learning that magic formula? Was he not more foolish, inasmuch as he was deluded into taking words for knowledge? It is that kind of teaching that one wants to get rid of, and banished out of science.

Make it as little as you like, but, unless that which is taught is based on actual observation and familiarity with facts, it is better left alone.

There are a great many people who imagine that elementary teaching might be properly carried out by teachers provided with only elementary knowledge. Let me assure you that that is the profoundest mistake in the world. There is nothing so difficult to do as to write a good elementary book, and there is nobody so hard to teach properly and well as people who know nothing about a subject, and I will tell you why. If I address an audience of persons who are occupied in the same line of work as myself, I can assume that they know a vast deal, and that they can find out the blunders I make. If they don't it is their fault and not mine; but when I appear before a body of people who know nothing about the matter, who take for gospel whatever I say, surely it becomes needful that I consider what I say, make sure that it will bear examination, and that I do not impose upon the credulity of those who have faith in me. In the second place, it involves that difficult process of knowing what you know so well that you can talk about it as you can talk about your ordinary business. A man can always talk about his own business. He can always make it plain; but, if his knowledge is hearsay, he is afraid to go beyond what he has recollected, and put it before those that are ignorant in such a shape that they shall comprehend it. That is why, to be a good elementary teacher, to teach the elements of any subject, requires most careful consideration, if you are a master of the subject; and, if you are not a master of it, it is needful you should familiarise yourself with so much as you are called upon to teach—soak yourself in it, so to speak—until you know it as part of your daily life and daily knowledge, and then you will be able to teach anybody. That is what I mean by practical

teachers, and, although the deficiency of such teachers is being remedied to a large extent, I think it is one which has long existed, and which has existed from no fault of those who undertook to teach, but because, until the last score of years, it absolutely was not possible for any one in a great many branches of science, whatever his desire might be, to get instruction which would enable him to be a good teacher of elementary things. All that is being rapidly altered, and I hope it will soon become a thing of the past.

The last point I have referred to is the question of the sufficiency of time. And here comes the rub. The teaching of science needs time, as any other subject; but it needs more time proportionally than other subjects, for the amount of work obviously done, if the teaching is to be, as I have said, practical. Work done in a laboratory involves a good deal of expenditure of time without always an obvious result, because we do not see anything of that quiet process of soaking the facts into the mind, which takes place through the organs of the senses. On this ground there must be ample time given to science teaching. What that amount of time should be is a point which I need not discuss now; in fact, it is a point which cannot be settled until one has made up one's mind about various other questions.

All, then, that I have to ask for, on behalf of the scientific people, if I may venture to speak for more than myself, is that you should put scientific teaching into what statesmen call the condition of "the most favoured nation"; that is to say, that it shall have as large a share of the time given to education as any other principal subject. You may say that that is a very vague statement, because the value of the allotment of time, under those circumstances, depends upon the number of principal subjects. It is x the time, and an unknown quantity of principal sub-

jects dividing that, and science taking shares with the rest. That shows that we cannot deal with this question fully until we have made up our minds as to what the principal subjects of education ought to be.

I know quite well that launching myself into this discussion is a very dangerous operation; that it is a very large subject, and one which is difficult to deal with, however much I may trespass upon your patience in the time allotted to me. But the discussion is so fundamental, it is so completely impossible to make up one's mind on these matters until one has settled the question, that I will even venture to make the experiment. A great lawyer-statesman and philosopher of a former age—I mean Francis Bacon—said that truth came out of error much more rapidly than it came out of confusion. There is a wonderful truth in that saying. Next to being right in this world, the best of all things is to be clearly and definitely wrong, because you will come out somewhere. If you go buzzing about between right and wrong, vibrating and fluctuating, you come out nowhere; but if you are absolutely and thoroughly and persistently wrong, you must, some of these days, have the extreme good fortune of knocking your head against a fact, and that sets you all straight again. So I will not trouble myself as to whether I may be right or wrong in what I am about to say, but at any rate I hope to be clear and definite; and then you will be able to judge for yourselves whether, in following out the train of thought I have to introduce, you knock your heads against facts or not.

I take it that the whole object of education is, in the first place, to train the faculties of the young in such a manner as to give their possessors the best chance of being happy and useful in their generation; and, in the second place, to furnish them with the most important portions of that immense capitalised experience of the human race

which we call knowledge of various kinds. I am using the term knowledge in its widest possible sense; and the question is, what subjects to select by training and discipline, in which the object I have just defined may be best attained.

I must call your attention further to this fact, that all the subjects of our thoughts—all feelings and propositions (leaving aside our sensations as the mere materials and occasions of thinking and feeling), all our mental furniture —may be classified under one of two heads—as either within the province of the intellect, something that can be put into propositions and affirmed or denied; or as within the province of feeling, or that which, before the name was defiled, was called the æsthetic side of our nature, and which can neither be proved nor disproved, but only felt and known.

According to the classification which I have put before you, then, the subjects of all knowledge are divisible into the two groups, matters of science and matters of art; for all things with which the reasoning faculty alone is occupied, come under the province of science; and in the broadest sense, and not in the narrow and technical sense in which we are now accustomed to use the word art, all things feelable, all things which stir our emotions, come under the term of art, in the sense of the subject-matter of the æsthetic faculty. So that we are shut up to this—that the business of education is, in the first place, to provide the young with the means and the habit of observation; and, secondly, to supply the subject-matter of knowledge either in the shape of science or of art, or of both combined.

Now, it is a very remarkable fact—but it is true of most things in this world—that there is hardly anything one-sided, or of one nature; and it is not immediately obvious what of the things that interest us may be regarded as pure science, and what may be regarded as pure art. It may be

that there are some peculiarly constituted persons who, before they have advanced far into the depths of geometry, find artistic beauty about it; but, taking the generality of mankind, I think it may be said that, when they begin to learn mathematics, their whole souls are absorbed in tracing the connection between the premises and the conclusion, and that to them geometry is pure science. So I think it may be said that mechanics and osteology are pure science. On the other hand, melody in music is pure art. You cannot reason about it; there is no proposition involved in it. So, again, in the pictorial art, an arabesque, or a "harmony in grey," touches none but the æsthetic faculty. But a great mathematician, and even many persons who are not great mathematicians, will tell you that they derive immense pleasure from geometrical reasonings. Everybody knows mathematicians speak of solutions and problems as "elegant," and they tell you that a certain mass of mystic symbols is "beautiful, quite lovely." Well, you do not see it. They do see it, because the intellectual process, the process of comprehending the reasons symbolised by these figures and these signs, confers upon them a sort of pleasure, such as an artist has in visual symmetry. Take a science of which I may speak with more confidence, and which is the most attractive of those I am concerned with. It is what we call morphology, which consists in tracing out the unity in variety of the infinitely diversified structures of animals and plants. I cannot give you any example of a thorough æsthetic pleasure more intensely real than a pleasure of this kind—the pleasure which arises in one's mind when a whole mass of different structures run into one harmony as the expression of a central law. That is where the province of art overlays and embraces the province of intellect. And, if I may venture to express an opinion on such a subject, the great majority of forms of art

are not in a sense what I just now defined them to be—pure art; but they derive much of their quality from simultaneous and even unconscious excitement of the intellect.

When I was a boy, I was very fond of music, and I am so now; and it so happened that I had the opportunity of hearing much good music. Among other things, I had abundant opportunities of hearing that great old master, Sebastian Bach. I remember perfectly well—though I knew nothing about music then, and, I may add, know nothing whatever about it now—the intense satisfaction and delight which I had in listening, by the hour together, to Bach's fugues. It is a pleasure which remains with me, I am glad to think; but, of late years, I have tried to find out the why and wherefore, and it has often occurred to me that the pleasure derived from musical compositions of this kind is essentially of the same nature as that which is derived from pursuits which are commonly regarded as purely intellectual. I mean, that the source of pleasure is exactly the same as in most of my problems in morphology—that you have the theme in one of the old master's works followed out in all its endless variations, always appearing and always reminding you of unity in variety. So in painting; what is called "truth to nature" is the intellectual element coming in, and truth to nature depends entirely upon the intellectual culture of the person to whom art is addressed. If you are in Australia, you may get credit for being a good artist—I mean among the natives—if you draw a kangaroo after a fashion. But, among men of higher civilisation, the intellectual knowledge we possess brings its criticism into our appreciation of works of art, and we are obliged to satisfy it, as well as the mere sense of beauty in colour and in outline. And so, the higher the culture and information of those whom art addresses, the more exact and precise must be what we call its "truth to nature."

If we turn to literature, the same thing is true, and you find works of literature which may be said to be pure art. A little song of Shakespeare or of Goethe is pure art; it is exquisitely beautiful, although its intellectual content may be nothing. A series of pictures is made to pass before your mind by the meaning of words, and the effect is a melody of ideas. Nevertheless, the great mass of the literature we esteem is valued, not merely because of having artistic form, but because of its intellectual content; and the value is the higher the more precise, distinct, and true is that intellectual content. And, if you will let me for a moment speak of the very highest forms of literature, do we not regard them as highest simply because the more we know the truer they seem, and the more competent we are to appreciate beauty the more beautiful they are? No man ever understands Shakespeare until he is old, though the youngest may admire him, the reason being that he satisfies the artistic instinct of the youngest and harmonises with the ripest and richest experience of the oldest.

I have said this much to draw your attention to what, in my mind, lies at the root of all this matter, and at the understanding of one another by the men of science on the one hand, and the men of literature, and history, and art, on the other. It is not a question whether one order of study or another should predominate. It is a question of what topics of education you shall select which will combine all the needful elements in such due proportion as to give the greatest amount of food, support, and encouragement to those faculties which enable us to appreciate truth, and to profit by those sources of innocent happiness which are open to us, and, at the same time, to avoid that which is bad, and coarse, and ugly, and keep clear of the multitude of pitfalls and dangers which beset those who break through the natural or moral laws.

I address myself, in this spirit, to the consideration of the question of the value of purely literary education. Is it good and sufficient, or is it insufficient and bad? Well, here I venture to say that there are literary educations and literary educations. If I am to understand by that term the education that was current in the great majority of middle-class schools, and upper schools too, in this country when I was a boy, and which consisted absolutely and almost entirely in keeping boys for eight or ten years at learning the rules of Latin and Greek grammar, construing certain Latin and Greek authors, and possibly making verses which, had they been English verses, would have been condemned as abominable doggerel—if that is what you mean by literary education, then I say it is scandalously insufficient and almost worthless. My reason for saying so is not from the point of view of science at all, but from the point of view of literature. I say the thing professes to be literary education that is not a literary education at all. It was not literature at all that was taught, but science in a very bad form. It is quite obvious that grammar is science and not literature. The analysis of a text by the help of the rules of grammar is just as much a scientific operation as the analysis of a chemical compound by the help of the rules of chemical analysis. There is nothing that appeals to the æsthetic faculty in that operation; and I ask multitudes of men of my own age, who went through this process, whether they ever had a conception of art or literature until they obtained it for themselves after leaving school? Then you may say, "If that is so, if the education was scientific, why cannot you be satisfied with it?" I say, because although it is a scientific training, it is of the most inadequate and inappropriate kind. If there is any good at all in scientific education it is that men should be trained, as I said before, to know things for themselves at first hand,

and that they should understand every step of the reason of that which they do.

I desire to speak with the utmost respect of that science —philology—of which grammar is a part and parcel; yet everybody knows that grammar, as it is usually learned at school, affords no scientific training. It is taught just as you would teach the rules of chess or draughts. On the other hand, if I am to understand by a literary education the study of the literatures of either ancient or modern nations—but especially those of antiquity, and especially that of ancient Greece; if this literature is studied, not merely from the point of view of philological science, and its practical application to the interpretation of texts, but as an exemplification of and commentary upon the principles of art; if you look upon the literature of a people as a chapter in the development of the human mind, if you work out this in a broad spirit, and with such collateral references to morals and politics, and physical geography, and the like as are needful to make you comprehend what the meaning of ancient literature and civilisation is— then, assuredly, it affords a splendid and noble education. But I still think it is susceptible of improvement, and that no man will ever comprehend the real secret of the difference between the ancient world and our present time, unless he has learned to see the difference which the late development of physical science has made between the thought of this day and the thought of that, and he will never see that difference, unless he has some practical insight into some branches of physical science; and you must remember that a literary education such as that which I have just referred to, is out of the reach of those whose school life is cut short at sixteen or seventeen.

But, you will say, all this is fault-finding; let us hear what you have in the way of positive suggestion. Then I

am bound to tell you that, if I could make a clean sweep of everything—I am very glad I cannot because I might, and probably should, make mistakes—but if I could make a clean sweep of everything and start afresh, I should, in the first place, secure that training of the young in reading and writing, and in the habit of attention and observation, both to that which is told them, and that which they see, which everybody agrees to. But in addition to that I should make it absolutely necessary for everybody, for a longer or shorter period, to learn to draw. Now, you may say, there are some people who cannot draw, however much they may be taught. I deny that *in toto,* because I never yet met with anybody who could not learn to write. Writing is a form of drawing; therefore if you give the same attention and trouble to drawing as you do to writing, depend upon it, there is nobody who cannot be made to draw, more or less well. Do not misapprehend me. I do not say for one moment you would make an artistic draughtsman. Artists are not made; they grow. You may improve the natural faculty in that direction, but you cannot make it; but you can teach simple drawing, and you will find it an implement of learning of extreme value. I do not think its value can be exaggerated, because it gives you the means of training the young in attention and accuracy, which are the two things in which all mankind are more deficient than in any other mental quality whatever. The whole of my life has been spent in trying to give my proper attention to things and to be accurate, and I have not succeeded as well as I could wish; and other people, I am afraid, are not much more fortunate. You cannot begin this habit too early, and I consider there is nothing of so great a value as the habit of drawing, to secure those two desirable ends.

Then we come to the subject-matter, whether scientific

or æsthetic, of education, and I should naturally have no question at all about teaching the elements of physical science of the kind I have sketched, in a practical manner; but among scientific topics, using the word scientific in the broadest sense, I would also include the elements of the theory of morals and of that of political and social life, which, strangely enough, it never seems to occur to anybody to teach a child. I would have the history of our own country, and of all the influences which have been brought to bear upon it, with incidental geography, not as a mere chronicle of reigns and battles, but as a chapter in the development of the race, and the history of civilisation.

Then with respect to æsthetic knowledge and discipline, we have happily in the English language one of the most magnificent storehouses of artistic beauty and of models of literary excellence which exists in the world at the present time. I have said before, and I repeat it here, that if a man cannot get literary culture of the highest kind out of his Bible, and Chaucer, and Shakespeare, and Milton, and Hobbes, and Bishop Berkeley, to mention only a few of our illustrious writers—I say, if he cannot get it out of those writers, he cannot get it out of anything; and I would assuredly devote a very large portion of the time of every English child to the careful study of the models of English writing of such varied and wonderful kind as we possess, and, what is still more important and still more neglected, the habit of using that language with precision, with force, and with art. I fancy we are almost the only nation in the world who seem to think that composition comes by nature. The French attend to their own language, the Germans study theirs; but Englishmen do not seem to think it is worth their while. Nor would I fail to include, in the course of study I am sketching, translations of all the best works of antiquity, or of the modern world. It is a very

desirable thing to read Homer in Greek; but if you don't happen to know Greek, the next best thing we can do is to read as good a translation of it as we have recently been furnished with in prose. You won't get all you would get from the original, but you may get a great deal; and to refuse to know this great deal because you cannot get all, seems to be as sensible as for a hungry man to refuse bread because he cannot get partridge. Finally, I would add instruction in either music or painting, or, if the child should be so unhappy, as sometimes happens, as to have no faculty for either of those, and no possibility of doing anything in any artistic sense with them, then I would see what could be done with literature alone; but I would provide, in the fullest sense, for the development of the æsthetic side of the mind. In my judgment, those are all the essentials of education for an English child. With that outfit, such as it might be made in the time given to education which is within the reach of nine-tenths of the population—with that outfit, an Englishman, within the limits of English life, is fitted to go anywhere, to occupy the highest positions, to fill the highest offices of the State, and to become distinguished in practical pursuits, in science, or in art. For, if he have the opportunity to learn all those things, and have his mind disciplined in the various directions the teaching of those topics would have necessitated, then, assuredly, he will be able to pick up, on his road through life, all the rest of the intellectual baggage he wants.

If the educational time at our disposition were sufficient there are one or two things I would add to those I have just now called the essentials; and perhaps you will be surprised to hear, though I hope you will not, that I should add, not more science, but one, or if possible, two languages. The knowledge of some other language than one's own is, in fact, of singular intellectual value. Many of the faults and

mistakes of the ancient philosophers are traceable to the fact that they knew no language but their own, and were often led into confusing the symbol with the thought which it embodied. I think it is Locke who says that one-half of the mistakes of philosophers have arisen from questions about words; and one of the safest ways of delivering yourself from the bondage of words is, to know how ideas look in words to which you are not accustomed. That is one reason for the study of language; another reason is, that it opens new fields in art and in science. Another is the practical value of such knowledge; and yet another is this, that if your languages are properly chosen, from the time of learning the additional languages you will know your own language better than ever you did. So, I say, if the time given to education permits, add Latin and German. Latin, because it is the key to nearly one-half of English and to all the Romance languages; and German, because it is the key to almost all the remainder of English, and helps you to understand a race from whom most of us have sprung, and who have a character and a literature of a fateful force in the history of the world, such as probably has been allotted to those of no other people, except the Jews, the Greeks, and ourselves. Beyond these, the essential and the eminently desirable elements of all education, let each man take up his special line—the historian devote himself to his history, the man of science to his science, the man of letters to his culture of that kind, and the artist to his special pursuit.

Bacon has prefaced some of his works with no more than this: *Franciscus Bacon sic cogitavit;* let "sic cogitavi" be the epilogue to what I have ventured to address to you to-night.

VII

A LOBSTER: OR THE STUDY OF ZOÖLOGY

[1861]

[This lecture was delivered to teachers at the South Kensington Museum in 1861, and was subsequently published by the Department of Science and Art. Ten years later Huxley instituted a regular summer course of study for teachers of science at South Kensington, the daily work consisting of an hour's lecture, followed by four hours' laboratory work. The biological laboratory, as it is now understood, may be said to date from this time, Jeffrey Parker tells us.

This lecture is a splendid illustration of Huxley's idea of the method of teaching science. The structure of the essay is clearly defined. An analysis of the essay should be made from Huxley's definition of the subject, his statement of its scope, and his development of the method of its study through his illustration—the lobster—which becomes a type case. His plea for demonstration or laboratory work as the chief aid in science teaching, and his explanation of how museums can be made to help the teaching of science, should be noted. And his argument for the teaching of science in elementary schools should be carefully worked out. Distinctly literary passages, such as the one on page 159, beginning "The whole of modern thought is steeped in science," should be read aloud. Nowhere else is Huxley's lucidity of style more in evidence than in this essay.]

Natural History is the name familiarly applied to the study of the properties of such natural bodies as minerals,

plants, and animals; the sciences which embody the knowledge man has acquired upon these subjects are commonly termed Natural Sciences, in contradistinction to other so-called "physical" sciences; and those who devote themselves especially to the pursuit of such sciences have been and are commonly termed "Naturalists."

Linnæus was a naturalist in this wide sense, and his "Systema Naturæ" was a work upon natural history, in the broadest acceptation of the term; in it, that great methodising spirit embodied all that was known in his time of the distinctive characters of minerals, animals, and plants. But the enormous stimulus which Linnæus gave to the investigation of nature soon rendered it impossible that any one man should write another "Systema Naturæ," and extremely difficult for any one to become even a naturalist such as Linnæus was.

Great as have been the advances made by all the three branches of science, of old included under the title of natural history, there can be no doubt that zoölogy and botany have grown in an enormously greater ratio than mineralogy; and hence, as I suppose, the name of "natural history" has gradually become more and more definitely attached to these prominent divisions of the subject, and by "naturalist" people have meant more and more distinctly to imply a student of the structure and function of living beings.

However this may be, it is certain that the advance of knowledge has gradually widened the distance between mineralogy and its old associates, while it has drawn zoölogy and botany closer together; so that of late years it has been found convenient (and indeed necessary) to associate the sciences which deal with vitality and all its phænomena under the common head of "biology;" and the biologists have come to repudiate any blood-relationship with their foster-brothers, the mineralogists.

Certain broad laws have a general application throughout both the animal and the vegetable worlds, but the ground common to these kingdoms of nature is not of very wide extent, and the multiplicity of details is so great, that the student of living beings finds himself obliged to devote his attention exclusively either to the one or the other. If he elects to study plants, under any aspect, we know at once what to call him. He is a botanist, and his science is botany. But if the investigation of animal life be his choice, the name generally applied to him will vary according to the kind of animals he studies, or the particular phænomena of animal life to which he confines his attention. If the study of man is his object, he is called an anatomist, or a physiologist, or an ethnologist; but if he dissects animals, or examines into the mode in which their functions are performed, he is a comparative anatomist or comparative physiologist. If he turns his attention to fossil animals, he is a palæontologist. If his mind is more particularly directed to the specific description, discrimination, classification, and the distribution of animals, he is termed a zoölogist.

For the purpose of the present discourse, however, I shall recognise none of these titles save the last, which I shall employ as the equivalent of botanist, and I shall use the term zoölogy as denoting the whole doctrine of animal life, in contradistinction to botany, which signifies the whole doctrine of vegetable life.

Employed in this sense, zoölogy, like botany, is divisible into three great but subordinate sciences, morphology, physiology, and distribution, each of which may, to a very great extent, be studied independently of the other.

Zoölogical morphology is the doctrine of animal form or structure. Anatomy is one of its branches; development is another; while classification is the expression of the rela-

tions which different animals bear to one another, in respect of their anatomy and their development.

Zoölogical distribution is the study of animals in relation to the terrestrial conditions which obtain now, or have obtained at any previous epoch of the earth's history.

Zoölogical physiology, lastly, is the doctrine of the functions or actions of animals. It regards animal bodies as machines impelled by certain forces, and performing an amount of work which can be expressed in terms of the ordinary forces of nature. The final object of physiology is to deduce the facts of morphology, on the one hand, and those of distribution on the other, from the laws of the molecular forces of matter.

Such is the scope of zoölogy. But if I were to content myself with the enunciation of these dry definitions, I should ill exemplify that method of teaching this branch of physical science, which it is my chief business to-night to recommend. Let us turn away then from abstract definitions. Let us take some concrete living thing, some animal, the commoner the better, and let us see how the application of common sense and common logic to the obvious facts it presents, inevitably leads us into all these branches of zoölogical science.

I have before me a lobster. When I examine it, what appears to be the most striking character it presents? Why, I observe that this part which we call the tail of the lobster, is made up of six distinct hard rings and a seventh terminal piece. If I separate one of the middle rings, say the third, I find it carries upon its under surface a pair of limbs or appendages, each of which consists of a stalk and two terminal pieces. So that I can represent a transverse section of the ring and its appendages upon the diagram board in this way.

If I now take the fourth ring, I find it has the same

structure, and so have the fifth and the second; so that, in each of these divisions of the tail, I find parts which correspond with one another, a ring and two appendages; and in each appendage a stalk and two end pieces. These corresponding parts are called, in the technical language of anatomy, "homologous parts." The ring of the third division is the "homologue" of the ring of the fifth, the appendage of the former is the homologue of the appendage of the latter. And, as each division exhibits corresponding parts in corresponding places, we say that all the divisions are constructed upon the same plan. But now let us consider the sixth division. It is similar to, and yet different from, the others. The ring is essentially the same as in the other divisions; but the appendages look at first as if they were very different; and yet when we regard them closely, what do we find? A stalk and two terminal divisions, exactly as in the others, but the stalk is very short and very thick, the terminal divisions are very broad and flat, and one of them is divided into two pieces.

I may say, therefore, that the sixth segment is like the others in plan, but that it is modified in its details.

The first segment is like the others, so far as its ring is concerned, and though its appendages differ from any of those yet examined in the simplicity of their structure, parts corresponding with the stem and one of the divisions of the appendages of the other segments can be readily discerned in them.

Thus it appears that the lobster's tail is composed of a series of segments which are fundamentally similar, though each presents peculiar modifications of the plan common to all. But when I turn to the forepart of the body I see at first, nothing but a great shield-like shell, called technically the "carapace," ending in front in a sharp spine, or

either side of which are the curious compound eyes, set upon the ends of stout movable stalks. Behind these, on the under side of the body, are two pairs of long feelers, or antennæ, followed by six pairs of jaws folded against one another over the mouth, and five pairs of legs, the foremost of these being the great pinchers, or claws, of the lobster.

It looks, at first, a little hopeless to attempt to find in this complex mass a series of rings, each with its pair of appendages, such as I have shown you in the abdomen, and yet it is not difficult to demonstrate their existence. Strip off the legs, and you will find that each pair is attached to a very definite segment of the under wall of the body; but these segments, instead of being the lower part of free rings, as in the tail, are such parts of rings which are all solidly united and bound together; and the like is true of the jaws, the feelers, and the eye-stalks, every pair of which is borne upon its own special segment. Thus the conclusion is gradually forced upon us, that the body of the lobster is composed of as many rings as there are pairs of appendages, namely, twenty in all, but that the six hindmost rings remain free and movable, while the fourteen front rings become firmly soldered together, their backs forming one continuous shield—the carapace.

Unity of plan, diversity in execution, is the lesson taught by the study of the rings of the body, and the same instruction is given still more emphatically by the appendages. If I examine the outermost jaw I find it consists of three distinct portions, an inner, a middle, and an outer, mounted upon a common stem; and if I compare this jaw with the legs behind it, or the jaws in front of it, I find it quite easy to see, that, in the legs, it is the part of the appendage which corresponds with the inner division, which becomes modified into what we know familiarly as the "leg," while

the middle division disappears, and the outer division is hidden under the carapace. Nor is it more difficult to discern that, in the appendages of the tail, the middle division appears again and the outer vanishes; while, on the other hand, in the foremost jaw, the so-called mandible, the inner division only is left; and, in the same way, the parts of the feelers and of the eye-stalks can be identified with those of the legs and jaws.

But whither does all this tend? To the very remarkable conclusion that a unity of plan, of the same kind as that discoverable in the tail or abdomen of the lobster, pervades the whole organisation of its skeleton, so that I can return to the diagram representing any one of the rings of the tail, which I drew upon the board, and by adding a third division to each appendage, I can use it as a sort of scheme or plan of any ring of the body. I can give names to all the parts of that figure, and then if I take any segment of the body of the lobster, I can point out to you exactly what modification the general plan has undergone in that particular segment; what part has remained movable, and what has become fixed to another; what has been excessively developed and metamorphosed and what has been suppressed.

But I imagine I hear the question, How is all this to be tested? No doubt it is a pretty and ingenious way of looking at the structure of any animal; but is it anything more? Does Nature acknowledge, in any deeper way, this unity of plan we seem to trace?

The objection suggested by these questions is a very valid and important one, and morphology was in an unsound state so long as it rested upon the mere perception of the analogies which obtain between fully formed parts. The unchecked ingenuity of speculative anatomists proved itself fully competent to spin any number of contradictory

hypotheses out of the same facts, and endless morphological dreams threatened to supplant scientific theory.

Happily, however, there is a criterion of morphological truth, and a sure test of all homologies. Our lobster has not always been what we see it; it was once an egg, a semi-fluid mass of yolk, not so big as a pin's head, contained in a transparent membrane, and exhibiting not the least trace of any one of those organs, the multiplicity and complexity of which, in the adult, are so surprising. After a time, a delicate patch of cellular membrane appeared upon one face of this yolk, and that patch was the foundation of the whole creature, the clay out of which it would be moulded. Gradually investing the yolk, it became subdivided by transverse constrictions into segments, the forerunners of the rings of the body. Upon the ventral surface of each of the rings thus sketched out, a pair of bud-like prominences made their appearance—the rudiments of the appendages of the ring. At first, all the appendages were alike, but, as they grew, most of them became distinguished into a stem and two terminal divisions, to which, in the middle part of the body, was added a third outer division; and it was only at a later period, that by the modification, or absorption, of certain of these primitive constituents, the limbs acquired their perfect form.

Thus the study of development proves that the doctrine of unity of plan is not merely a fancy, that it is not merely one way of looking at the matter, but that it is the expression of deep-seated natural facts. The legs and jaws of the lobster may not merely be regarded as modifications of a common type—in fact and in nature they are so—the leg and the jaw of the young animal being, at first, indistinguishable.

These are wonderful truths, the more so because the zoölogist finds them to be of universal application. The

investigation of a polype, of a snail, of a fish, of a horse, or of a man, would have led us, though by a less easy path, perhaps, to exactly the same point. Unity of plan everywhere lies hidden under the mask of diversity of structure —the complex is everywhere evolved out of the simple. Every animal has at first the form of an egg, and every animal and every organic part, in reaching its adult state, passes through conditions common to other animals and other adult parts; and this leads me to another point. I have hitherto spoken as if the lobster were alone in the world, but, as I need hardly remind you, there are myriads of other animal organisms. Of these, some, such as men, horses, birds, fishes, snails, slugs, oysters, corals, and sponges, are not in the least like the lobster. But other animals, though they may differ a good deal from the lobster, are yet either very like it, or are like something that is like it. The crayfish, the rock lobster, and the prawn, and the shrimp, for example, however different, are yet so like lobsters, that a child would group them as of the lobster kind, in contradistinction to snails and slugs; and these last again would form a kind by themselves, in contradistinction to cows, horses, and sheep, the cattle kind.

But this spontaneous grouping into "kinds" is the first essay of the human mind at classification, or the calling by a common name of those things that are alike, and the arranging them in such a manner as best to suggest the sum of their likenesses and unlikenesses to other things.

Those kinds which include no other subdivisions than the sexes, or various breeds, are called, in technical language, species. The English lobster is a species, our crayfish is another, our prawn is another. In other countries, however, there are lobsters, crayfish, and prawns, very like ours, and yet presenting sufficient differences to deserve distinction. Naturalists, therefore, express this resem-

blance and this diversity by grouping them as distinct species of the same "genus." But the lobster and the crayfish, though belonging to distinct genera, have many features in common, and hence are grouped together in an assemblage which is called a family. More distant resemblances connect the lobster with the prawn and the crab, which are expressed by putting all these into the same order. Again, more remote, but still very definite, resemblances unite the lobster with the woodlouse, the king crab, the water flea, and the barnacle, and separate them from all other animals; whence they collectively constitute the larger group, or class, *Crustacea.* But the *Crustacea* exhibit many peculiar features in common with insects, spiders, and centipedes, so that these are grouped into the still larger assemblage or "province" *Articulata;* and, finally, the relations which these have to worms and other lower animals, are expressed by combining the whole vast aggregate into the sub-kingdom of *Annulosa.*

If I had worked my way from a sponge instead of a lobster, I should have found it associated, by like ties, with a great number of other animals into the sub-kingdom *Protozoa;* if I had selected a fresh-water polype or a coral, the members of what naturalists term the sub-kingdom *Cœlenterata,* would have grouped themselves around my type; had a snail been chosen, the inhabitants of all univalve and bivalve, land and water, shells, the lamp shells, the squids, and the sea-mat would have gradually linked themselves on to it as members of the same sub-kingdom of *Mollusca;* and finally, starting from man, I should have been compelled to admit first, the ape, the rat, the horse, the dog, into the same class; and then the bird, the crocodile, the turtle, the frog, and the fish, into the same sub-kingdom of *Vertebrata.*

And if I had followed out all these various lines of

classification fully, I should discover in the end that there was no animal, either recent or fossil, which did not at once fall into one or other of these sub-kingdoms. In other words, every animal is organised upon one or other of the five, or more, plans, the existence of which renders our classification possible. And so definitely and precisely marked is the structure of each animal, that, in the present state of our knowledge, there is not the least evidence to prove that a form, in the slightest degree transitional between any of the two groups *Vertebrata, Annulosa, Mollusca,* and *Cœlenterata,* either exists, or has existed, during that period of the earth's history which is recorded by the geologist.[1] Nevertheless, you must not for a moment suppose, because no such transitional forms are known, that the members of the sub-kingdoms are disconnected from, or independent of, one another. On the contrary, in their earliest condition they are all similar, and the primordial germs of a man, a dog, a bird, a fish, a beetle, a snail, and a polype are, in no essential structural respects, distinguishable.

In this broad sense, it may with truth be said, that all living animals, and all those dead faunæ which geology reveals, are bound together by an all-pervading unity of organisation, of the same character, though not equal in degree, to that which enables us to discern one and the same plan amidst the twenty different segments of a lobster's body. Truly it has been said, that to a clear eye the smallest fact is a window through which the Infinite may be seen.

Turning from these purely morphological considerations, let us now examine into the manner in which the attentive study of the lobster impels us into other lines of research.

[1 The different grouping necessitated by later knowledge does not affect the principle of the argument.—1894.]

Lobsters are found in all the European seas; but on the opposite shores of the Atlantic and in the seas of the southern hemisphere they do not exist. They are, however, represented in these regions by very closely allied, but distinct forms—the *Homarus Americanus* and the *Homarus Capensis:* so that we may say that the European has one species of *Homarus;* the American, another; the African, another; and thus the remarkable facts of geographical distribution begin to dawn upon us.

Again, if we examine the contents of the earth's crust, we shall find in the latter of those deposits, which have served as the great burying grounds of past ages, numberless lobster-like animals, but none so similar to our living lobster as to make zoölogists sure that they belonged even to the same genus. If we go still further back in time, we discover, in the oldest rocks of all, the remains of animals, constructed on the same general plan as the lobster, and belonging to the same great group of *Crustacea;* but for the most part totally different from the lobster, and indeed from any other living form of crustacean; and thus we gain a notion of that successive change of the animal population of the globe, in past ages, which is the most striking fact revealed by geology.

Consider now, where our inquiries have led us. We studied our type morphologically when we determined its anatomy and its development, and when comparing it, in these respects, with other animals, we made out its place in a system of classification. If we were to examine every animal in a similar manner, we should establish a complete body of zoölogical morphology.

Again, we investigated the distribution of our type in space and in time, and, if the like had been done with every animal, the sciences of geographical and geological distribution would have attained their limit.

But you will observe one remarkable circumstance, that, up to this point, the question of the life of these organisms has not come under consideration. Morphology and distribution might be studied almost as well, if animals and plants were a peculiar kind of crystals, and possessed none of those functions which distinguish living beings so remarkably. But the facts of morphology and distribution have to be accounted for, and the science, the aim of which it is to account for them, is Physiology.

Let us return to our lobster once more. If we watched the creature in its native element, we should see it climbing actively the submerged rocks, among which it delights to live, by means of its strong legs; or swimming by powerful strokes of its great tail, the appendages of the sixth joint of which are spread out into a broad fan-like propeller: seize it, and it will show you that its great claws are no mean weapons of offence; suspend a piece of carrion among its haunts, and it will greedily devour it, tearing and crushing the flesh by means of its multitudinous jaws.

Suppose that we had known nothing of the lobster but as an inert mass, an organic crystal, if I may use the phrase, and that we could suddenly see it exerting all these powers, what wonderful new ideas and new questions would arise in our minds! The great new question would be, "How does all this take place?" The chief new idea would be, the idea of adaptation to purpose—the notion, that the constituents of animal bodies are not mere unconnected parts, but organs working together to an end. Let us consider the tail of the lobster again from this point of view. Morphology has taught us that it is a series of segments composed of homologous parts, which undergo various modifications—beneath and through which a common plan of formation is discernible. But if I look at the same part physiologically, I see that it is a most beau-

tifully constructed organ of locomotion, by means of which the animal can swiftly propel itself either backwards or forwards.

But how is this remarkable propulsive machine made to perform its functions? If I were suddenly to kill one of these animals and to take out all the soft parts, I should find the shell to be perfectly inert, to have no more power of moving itself than is possessed by the machinery of a mill when disconnected from its steam-engine or water-wheel. But if I were to open it, and take out the viscera only, leaving the white flesh, I should perceive that the lobster could bend and extend its tail as well as before. If I were to cut off the tail, I should cease to find any spontaneous motion in it; but on pinching any portion of the flesh, I should observe that it underwent a very curious change—each fibre becoming shorter and thicker. By this act of contraction, as it is termed, the parts to which the ends of the fibre are attached are, of course, approximated; and according to the relations of their points of attachment to the centres of motions of the different rings, the bending or the extension of the tail results. Close observation of the newly-opened lobster would soon show that all its movements are due to the same cause—the shortening and thickening of these fleshy fibres, which are technically called muscles.

Here, then, is a capital fact. The movements of the lobster are due to muscular contractility. But why does a muscle contract at one time and not at another? Why does one whole group of muscles contract when the lobster wishes to extend his tail, and another group when he desires to bend it? What is it originates, directs, and controls the motive power?

Experiment, the great instrument for the ascertainment of truth in physical science, answers this question for us.

In the head of the lobster there lies a small mass of that peculiar tissue which is known as nervous substance. Cords of similar matter connect this brain of the lobster, directly or indirectly, with the muscles. Now, if these communicating cords are cut, the brain remaining entire, the power of exerting what we call voluntary motion in the parts below the section is destroyed; and, on the other hand, if, the cords remaining entire, the brain mass be destroyed, the same voluntary mobility is equally lost. Whence the inevitable conclusion is, that the power of originating these motions resides in the brain and is propagated along the nervous cords.

In the higher animals the phænomena which attend this transmission have been investigated, and the exertion of the peculiar energy which resides in the nerves has been found to be accompanied by a disturbance of the electrical state of their molecules.

If we could exactly estimate the signification of this disturbance; if we could obtain the value of a given exertion of nerve force by determining the quantity of electricity, or of heat, of which it is the equivalent; if we could ascertain upon what arrangement, or other condition of the molecules of matter, the manifestation of the nervous and muscular energies depends (and doubtless science will some day or other ascertain these points), physiologists would have attained their ultimate goal in this direction; they would have determined the relation of the motive force of animals to the other forms of force found in nature; and if the same process had been successfully performed for all the operations which are carried on in, and by, the animal frame, physiology would be perfect, and the facts of morphology and distribution would be deducible from the laws which physiologists had established, combined with those determining the condition of the surrounding universe.

There is not a fragment of the organism of this humble animal whose study would not lead us into regions of thought as large as those which I have briefly opened up to you; but what I have been saying, I trust, has not only enabled you to form a conception of the scope and purport of zoölogy, but has given you an imperfect example of the manner in which, in my opinion, that science, or indeed any physical science, may be best taught. The great matter is, to make teaching real and practical, by fixing the attention of the student on particular facts; but at the same time it should be rendered broad and comprehensive, by constant reference to the generalisations of which all particular facts are illustrations. The lobster has served as a type of the whole animal kingdom, and its anatomy and physiology have illustrated for us some of the greatest truths of biology. The student who has once seen for himself the facts which I have described, has had their relations explained to him, and has clearly comprehended them, has, so far, a knowledge of zoölogy, which is real and genuine, however limited it may be, and which is worth more than all the mere reading knowledge of the science he could ever acquire. His zoölogical information is, so far, knowledge and not mere hearsay.

And if it were my business to fit you for the certificate in zoölogical science granted by this department, I should pursue a course precisely similar in principle to that which I have taken to-night. I should select a fresh-water sponge, a fresh-water polype or a *Cyanœa,* a fresh-water mussel, a lobster, a fowl, as types of the five primary divisions of the animal kingdom. I should explain their structure very fully, and show how each illustrated the great principles of zoölogy. Having gone very carefully and fully over this ground, I should feel that you had a safe foundation, and I should then take you in the same way, but less

minutely, over similarly selected illustrative types of the classes; and then I should direct your attention to the special forms enumerated under the head of types, in this syllabus, and to the other facts there mentioned.

That would, speaking generally, be my plan. But I have undertaken to explain to you the best mode of acquiring and communicating a knowledge of zoölogy, and you may therefore fairly ask me for a more detailed and precise account of the manner in which I should propose to furnish you with the information I refer to.

My own impression is, that the best model for all kinds of training in physical science is that afforded by the method of teaching anatomy, in use in the medical schools. This method consists of three elements—lectures, demonstrations, and examinations.

The object of lectures is, in the first place, to awaken the attention and excite the enthusiasm of the student; and this, I am sure, may be effected to a far greater extent by the oral discourse and by the personal influence of a respected teacher than in any other way. Secondly, lectures have the double use of guiding the student to the salient points of a subject, and at the same time forcing him to attend to the whole of it, and not merely to that part which takes his fancy. And lastly, lectures afford the student the opportunity of seeking explanations of those difficulties which will, and indeed ought to, arise in the course of his studies.

What books shall I read? is a question constantly put by the student to the teacher. My reply usually is, "None: write your notes out carefully and fully; strive to understand them thoroughly; come to me for the explanation of anything you cannot understand; and I would rather you did not distract your mind by reading." A properly composed course of lectures ought to contain fully as much

matter as a student can assimilate in the time occupied by its delivery; and the teacher should always recollect that his business is to feed, and not to cram the intellect. Indeed, I believe that a student who gains from a course of lectures the simple habit of concentrating his attention upon a definitely limited series of facts, until they are thoroughly mastered, has made a step of immeasurable importance.

But, however good lectures may be, and however extensive the course of reading by which they are followed up, they are but accessories to the great instrument of scientific teaching—demonstration. If I insist unweariedly, nay fanatically, upon the importance of physical science as an educational agent, it is because the study of any branch of science, if properly conducted, appears to me to fill up a void left by all other means of education. I have the greatest respect and love for literature; nothing would grieve me more than to see literary training other than a very prominent branch of education: indeed, I wish that real literary discipline were far more attended to than it is; but I cannot shut my eyes to the fact, that there is a vast difference between men who have had a purely literary, and those who have had a sound scientific training.

Seeking for the cause of this difference, I imagine I can find it in the fact that, in the world of letters, learning and knowledge are one, and books are the source of both; whereas in science, as in life, learning and knowledge are distinct, and the study of things, and not of books, is the source of the latter.

All that literature has to bestow may be obtained by reading and by practical exercise in writing and in speaking; but I do not exaggerate when I say, that none of the best gifts of science are to be won by these means. On the contrary, the great benefit which a scientific education

bestows, whether as training or as knowledge, is dependent upon the extent to which the mind of the student is brought into immediate contact with facts—upon the degree to which he learns the habit of appealing directly to Nature, and of acquiring through his senses concrete images of those properties of things, which are, and always will be, but approximately expressed in human language. Our way of looking at Nature, and of speaking about her, varies from year to year; but a fact once seen, a relation of cause and effect once demonstratively apprehended, are possessions which neither change nor pass away, but, on the contrary, form fixed centres, about which other truths aggregate by natural affinity.

Therefore, the great business of the scientific teacher is, to imprint the fundamental, irrefragable facts of his science, not only by words upon the mind, but by sensible impressions upon the eye, and ear, and touch of the student, in so complete a manner that every term used, or law enunciated, should afterwards call up vivid images of the particular structural, or other, facts which furnished the demonstration of the law, or the illustration of the term.

Now this important operation can only be achieved by constant demonstration, which may take place to a certain imperfect extent during a lecture, but which ought also to be carried on independently, and which should be addressed to each individual student, the teacher endeavouring, not so much to show a thing to the learner, as to make him see it for himself.

I am well aware that there are great practical difficulties in the way of effectual zoölogical demonstrations. The dissection of animals is not altogether pleasant, and requires much time; nor is it easy to secure an adequate supply of the needful specimens. The botanist has here a great advantage; his specimens are easily obtained, are

clean and wholesome, and can be dissected in a private house as well as anywhere else; and hence, I believe, the fact that botany is so much more readily and better taught than its sister science. But, be it difficult or be it easy, if zoölogical science is to be properly studied, demonstration, and, consequently, dissection, must be had. Without it, no man can have a really sound knowledge of animal organisation.

A good deal may be done, however, without actual dissection on the student's part, by demonstration upon specimens and preparations; and in all probability it would not be very difficult, were the demand sufficient, to organise collections of such objects, sufficient for all the purposes of elementary teaching, at a comparatively cheap rate. Even without these, much might be effected, if the zoölogical collections, which are open to the public, were arranged according to what has been termed the "typical principle"; that is to say, if the specimens exposed to public view were so selected that the public could learn something from them, instead of being, as at present, merely confused by their multiplicity. For example, the grand ornithological gallery at the British Museum contains between two and three thousand species of birds, and sometimes five or six specimens of a species. They are very pretty to look at, and some of the cases are, indeed, splendid; but I will undertake to say, that no man but a professed ornithologist has ever gathered much information from the collection. Certainly, no one of the tens of thousands of the general public who have walked through that gallery ever knew more about the essential peculiarities of birds when he left the gallery than when he entered it. But if, somewhere in that vast hall, there were a few preparations, exemplifying the leading structural peculiarities and the mode of development of a common fowl; if the types of

the genera, the leading modifications in the skeleton, in the plumage at various ages, in the mode of nidification, and the like, among birds, were displayed; and if the other specimens were put away in a place where the men of science, to whom they are alone useful, could have free access to them, I can conceive that this collection might become a great instrument of scientific education.

The last implement of the teacher to which I have adverted is examination—a means of education now so thoroughly understood that I need hardly enlarge upon it. I hold that both written and oral examinations are indispensable, and, by requiring the description of specimens, they may be made to supplement demonstration.

Such is the fullest reply the time at my disposal will allow me to give to the question—how may a knowledge of zoölogy be best acquired and communicated?

But there is a previous question which may be moved, and which, in fact, I know many are inclined to move. It is the question, why should teachers be encouraged to acquire a knowledge of this, or any other branch of physical science? What is the use, it is said, of attempting to make physical science a branch of primary education? Is it not probable that teachers, in pursuing such studies, will be led astray from the acquirement of more important but less attractive knowledge? And, even if they can learn something of science without prejudice to their usefulness, what is the good of their attempting to instil that knowledge into boys whose real business is the acquisition of reading, writing, and arithmetic?

These questions are, and will be, very commonly asked, for they arise from that profound ignorance of the value and true position of physical science, which infests the minds of the most highly educated and intelligent classes of the community. But if I did not feel well assured that

they are capable of being easily and satisfactorily answered; that they have been answered over and over again; and that the time will come when men of liberal education will blush to raise such questions—I should be ashamed of my position here to-night. Without doubt, it is your great and very important function to carry out elementary education; without question, anything that should interfere with the faithful fulfilment of that duty on your part would be a great evil; and if I thought that your acquirement of the elements of physical science, and your communication of those elements to your pupils, involved any sort of interference with your proper duties, I should be the first person to protest against your being encouraged to do anything of the kind.

But is it true that the acquisition of such a knowledge of science as is proposed, and the communication of that knowledge, are calculated to weaken your usefulness? Or may I not rather ask, is it possible for you to discharge your functions properly without these aids?

What is the purpose of primary intellectual education? I apprehend that its first object is to train the young in the use of those tools wherewith men extract knowledge from the ever-shifting succession of phænomena which pass before their eyes; and that its second object is to inform them of the fundamental laws which have been found by experience to govern the course of things, so that they may not be turned out into the world naked, defenceless, and a prey to the events they might control.

A boy is taught to read his own and other languages, in order that he may have access to infinitely wider stores of knowledge than could ever be opened to him by oral intercourse with his fellow men; he learns to write, that his means of communication with the rest of mankind may be indefinitely enlarged, and that he may record and store

up the knowledge he acquires. He is taught elementary mathematics, that he may understand all those relations of number and form, upon which the transactions of men, associated in complicated societies, are built, and that he may have some practice in deductive reasoning.

All these operations of reading, writing, and ciphering, are intellectual tools, whose use should, before all things, be learned, and learned thoroughly; so that the youth may be enabled to make his life that which it ought to be, a continual progress in learning and in wisdom.

But, in addition, primary education endeavours to fit a boy out with a certain equipment of positive knowledge. He is taught the great laws of morality; the religion of his sect; so much history and geography as will tell him where the great countries of the world are, what they are, and how they have become what they are.

Without doubt all these are most fitting and excellent things to teach a boy; I should be very sorry to omit any of them from any scheme of primary intellectual education. The system is excellent, so far as it goes.

But if I regard it closely, a curious reflection arises. I suppose that, fifteen hundred years ago, the child of any well-to-do Roman citizen was taught just these same things; reading and writing in his own, and, perhaps, the Greek tongue; the elements of mathematics; and the religion, morality, history, and geography current in his time. Furthermore, I do not think I err in affirming, that, if such a Christian Roman boy, who had finished his education, could be transplanted into one of our public schools, and pass through its course of instruction, he would not meet with a single unfamiliar line of thought; amidst all the new facts he would have to learn, not one would suggest a different mode of regarding the universe from that current in his own time.

And yet surely there is some great difference between the civilisation of the fourth century and that of the nineteenth, and still more between the intellectual habits and tone of thought of that day and this?

And what has made this difference? I answer fearlessly —the prodigious development of physical science within the last two centuries.

Modern civilisation rests upon physical science; take away her gifts to our own country, and our position among the leading nations of the world is gone to-morrow; for it is physical science only that makes intelligence and moral energy stronger than brute force.

The whole of modern thought is steeped in science; it has made its way into the works of our best poets, and even the mere man of letters, who affects to ignore and despise science, is unconsciously impregnated with her spirit, and indebted for his best products to her methods. I believe that the greatest intellectual revolution mankind has yet seen is now slowly taking place by her agency. She is teaching the world that the ultimate court of appeal is observation and experiment, and not authority; she is teaching it to estimate the value of evidence; she is creating a firm and living faith in the existence of immutable moral and physical laws, perfect obedience to which is the highest possible aim of an intelligent being.

But of all this your old stereotyped system of education takes no note. Physical science, its methods, its problems, and its difficulties, will meet the poorest boy at every turn, and yet we educate him in such a manner that he shall enter the world as ignorant of the existence of the methods and facts of science as the day he was born. The modern world is full of artillery; and we turn out our children to do battle in it, equipped with the shield and sword of an ancient gladiator.

Posterity will cry shame on us if we do not remedy this deplorable state of things. Nay, if we live twenty years longer, our own consciences will cry shame on us.

It is my firm conviction that the only way to remedy it is to make the elements of physical science an integral part of primary education. I have endeavoured to show you how that may be done for that branch of science which it is my business to pursue; and I can but add, that I should look upon the day when every schoolmaster throughout this land was a centre of genuine, however rudimentary, scientific knowledge, as an epoch in the history of the country.

But let me entreat you to remember my last words. Addressing myself to you, as teachers, I would say, mere book learning in physical science is a sham and a delusion—what you teach, unless you wish to be impostors, that you must first know; and real knowledge in science means personal acquaintance with the facts, be they few or many.[1]

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[1] It has been suggested to me that these words may be taken to imply a discouragement on my part of any sort of scientific instruction which does not give an acquaintance with the facts at first hand. But this is not my meaning. The ideal of scientific teaching is, no doubt, a system by which the scholar sees every fact for himself, and the teacher supplies only the explanations. Circumstances, however, do not often allow of the attainment of that ideal, and we must put up with the next best system—one in which the scholar takes a good deal on trust from a teacher, who, knowing the facts by his own knowledge, can describe them with so much vividness as to enable his audience to form competent ideas concerning them. The system which I repudiate is that which allows teachers who have not come into direct contact with the leading facts of a science to pass their second-hand information on. The scientific virus, like vaccine lymph, if passed through too long a succession of organisms, will lose all its effect in protecting the young against the intellectual epidemics to which they are exposed.

[The remarks on p. 155 applied to the Natural History Collection of the British Museum in 1861. The visitor to the Natural History Museum in 1894 need go no further than the Great Hall to see the realisation of my hopes by the present Director.]

VIII

ON THE STUDY OF BIOLOGY

[1876]

[This lecture was delivered in connection with the Loan Collection of Scientific Apparatus, December 16, 1876, at the South Kensington Museum. In it Huxley discusses the origin of the word Biology, the function of museums, and, above all, the use of Biology in helping "to give people right ideas, which are essential to the foundation of right practice, and to remove wrong ideas, which are the no less essential foundations and fertile mothers of every description of error in practice" (p. 169).

This essay furnishes another instance of Huxley's powers of clear exposition. It should be outlined in detail according to the plan of treatment the author suggests at the opening: "what Biology is; why it should be studied; how it should be studied; and when it should be studied." As in the other essays in this collection, a study of Huxley's words, sentences, and paragraphs would profit the student.]

It is my duty to-night to speak about the study of Biology, and while it may be that there are many of my audience who are quite familiar with that study, yet as a lecturer of some standing, it would, I know by experience, be very bad policy on my part to suppose such to be extensively the case. On the contrary, I must imagine that there are many of you who would like to know what Biology is; that there are others who have that amount of informa-

tion, but would nevertheless gladly hear why it should be worth their while to study Biology; and yet others, again, to whom these two points are clear, but who desire to learn how they had best study it, and, finally, when they had best study it.

I shall, therefore, address myself to the endeavour to give you some answer to these four questions—what Biology is; why it should be studied; how it should be studied; and when it should be studied.

In the first place, in respect to what Biology is, there are, I believe, some persons who imagine that the term "Biology" is simply a new-fangled denomination, a neologism in short, for what used to be known under the title of "Natural History"; but I shall try to show you, on the contrary, that the word is the expression of the growth of science during the last 200 years, and came into existence half a century ago.

At the revival of learning, knowledge was divided into two kinds—the knowledge of nature and the knowledge of man; for it was the current idea then (and a great deal of that ancient conception still remains) that there was a sort of essential antithesis, not to say antagonism, between nature and man; and that the two had not very much to do with one another, except that the one was oftentimes exceedingly troublesome to the other. Though it is one of the salient merits of our great philosophers of the seventeenth century, that they recognised but one scientific method, applicable alike to man and to nature, we find this notion of the existence of a broad distinction between nature and man in the writings both of Bacon and of Hobbes of Malmesbury; and I have brought with me that famous work which is now so little known, greatly as it deserves to be studied, "The Leviathan," in order that I may put to you in the wonderfully terse and clear language

of Thomas Hobbes, what was his view of the matter. He says:—

"The register of knowledge of fact is called history. Whereof there be two sorts, one called natural history; which is the history of such facts or effects of nature as have no dependence on man's will; such as are the histories of metals, plants, animals, regions, and the like. The other is civil history; which is the history of the voluntary actions of men in commonwealths."

So that all history of fact was divided into these two great groups of natural and of civil history. The Royal Society was in course of foundation about the time that Hobbes was writing this book, which was published in 1651; and that Society was termed a "Society for the Improvement of Natural Knowledge," which was then nearly the same thing as a "Society for the Improvement of Natural History." As time went on, and the various branches of human knowledge became more distinctly developed and separated from one another, it was found that some were much more susceptible of precise mathematical treatment than others. The publication of the "Principia" of Newton, which probably gave a greater stimulus to physical science than any work ever published before, or which is likely to be published hereafter, showed that precise mathematical methods were applicable to those branches of science such as astronomy, and what we now call physics, which occupy a very large portion of the domain of what the older writers understood by natural history. And inasmuch as the partly deductive and partly experimental methods of treatment to which Newton and others subjected these branches of human knowledge, showed that the phænomena of nature which belonged to them were susceptible of explanation, and thereby came within the reach of what was called "philosophy," in those days; so

much of this kind of knowledge as was not included under astronomy came to be spoken of as "natural philosophy" —a term which Bacon had employed in a much wider sense. Time went on, and yet other branches of science developed themselves. Chemistry took a definite shape; and since all these sciences, such as astronomy, natural philosophy, and chemistry, were susceptible either of mathematical treatment or of experimental treatment, or of both, a broad distinction was drawn between the experimental branches of what had previously been called natural history and the observational branches—those in which experiment was (or appeared to be) of doubtful use, and where, at that time, mathematical methods were inapplicable. Under these circumstances the old name of "Natural History" stuck by the residuum by those phænomena which were not, at that time, susceptible of mathematical or experimental treatment; that is to say, those phænomena of nature which come now under the general heads of physical geography, geology, mineralogy, the history of plants, and the history of animals. It was in this sense that the term was understood by the great writers of the middle of the last century —Buffon and Linnæus—by Buffon in his great work, the "Histoire Naturelle Générale," and by Linnæus in his splendid achievement, the "Systema Naturæ." The subjects they deal with are spoken of as "Natural History," and they called themselves and were called "Naturalists." But you will observe that this was not the original meaning of these terms; but that they had, by this time, acquired a signification widely different from that which they possessed primitively.

The sense in which "Natural History" was used at the time I am now speaking of has, to a certain extent, endured to the present day. There are now in existence in some of our northern universities, chairs of "Civil and Natural

History" in which "Natural History" is used to indicate exactly what Hobbes and Bacon meant by that term. The unhappy incumbent of the chair of Natural History is, or was, supposed to cover the whole ground of geology, mineralogy, and zoölogy, perhaps even botany, in his lectures.

But as science made the marvellous progress which it did make at the latter end of the last and the beginning of the present century, thinking men began to discern that under this title of "Natural History" there were included very heterogeneous constituents—that, for example, geology and mineralogy were, in many respects, widely different from botany and zoölogy; that a man might obtain an extensive knowledge of the structure and functions of plants and animals without having need to enter upon the study of geology or mineralogy, and *vice versa;* and, further as knowledge advanced, it became clearer that there was a great analogy, a very close alliance, between those two sciences, of botany and zoölogy which deal with human beings, while they are much more widely separated from all other studies. It is due to Buffon to remark that he clearly recognised this great fact. He says: "Ces deux genres d'êtres organisés [les animaux et les végétaux] ont beaucoup plus de propriétés communes que de différences réelles." Therefore, it is not wonderful that, at the beginning of the present century, in two different countries, and so far as I know, without any intercommunication, two famous men clearly conceived the notion of uniting the sciences which deal with living matter into one whole, and of dealing with them as one discipline. In fact, I may say that there were three men to whom this idea occurred contemporaneously, although there were but two who carried it into effect, and only one who worked it out completely. The persons to whom I refer were the eminent physiologist Bichat, and the great naturalist Lamarck, in

France; and a distinguished German, Treviranus. Bichat[1] assumed the existence of a special group of "physiological" sciences. Lamarck, in a work published in 1801,[2] for the first time made use of the name "Biologie," from the two Greek words which signify a discourse upon life and living things. About the same time it occurred to Treviranus, that all those sciences which deal with living matter are essentially and fundamentally one, and ought to be treated as a whole; and, in the year 1802, he published the first volume of what he also called "Biologie." Treviranus's great merit lies in this, that he worked out his idea, and wrote the very remarkable book to which I refer. It consists of six volumes, and occupied its author for twenty years—from 1802 to 1822.

That is the origin of the term "Biology"; and that is how it has come about that all clear thinkers and lovers of consistent nomenclature have substituted for the old confusing name of "Natural History," which has conveyed so many meanings, the term "Biology," which denotes the whole of the sciences which deal with living things, whether they be animals or whether they be plants. Some little time ago—in the course of this year, I think—I was favoured by a learned classic, Dr. Field of Norwich, with a disquisition, in which he endeavoured to prove that, from a philological point of view, neither Treviranus nor Lamarck had any right to coin this new word "Biology" for their purpose; that, in fact, the Greek word "Bios" had relation only to human life and human affairs, and that a different word was employed by the Greeks when they wished to speak of the life of animals and plants. So Dr. Field tells us we are all wrong in using the term biology,

[1] See the distinction between the "sciences physiques" and the "sciences physiologiques" in the *Anatomie Générale*, 1801.

[2] *Hydrogéologie*, an. x. (1801).

and that we ought to employ another; only he is not sure about the propriety of that which he proposes as a substitute. It is a somewhat hard one—"zootocology." I am sorry we are wrong, because we are likely to continue so. In these matters we must have some sort of "Statute of Limitations." When a name has been employed for half a century, persons of authority [1] have been using it, and its sense has become well understood, I am afraid people will go on using it, whatever the weight of philological objection.

Now that we have arrived at the origin of this word "Biology," the next point to consider is: What ground does it cover? I have said that in its strict technical sense, it denotes all the phænomena which are exhibited by living things, as distinguished from those which are not living; but while that is all very well, so long as we confine ourselves to the lower animals and to plants, it lands us in considerable difficulties when we reach the higher forms of living things. For whatever view we may entertain about the nature of man, one thing is perfectly certain, that he is a living creature. Hence, if our definition is to be interpreted strictly, we must include man and all his ways and works under the head of Biology; in which case, we should find that psychology, politics, and political economy would be absorbed into the province of Biology. In fact, civil history would be merged in natural history. In strict logic it may be hard to object to this course, because no one can doubt that the rudiments and outlines of our own mental phænomena are traceable among the lower animals. They have their economy and their polity, and if, as is

[1] "The term *Biology*, which means exactly what we wish to express, *the Science of Life*, has often been used, and has of late become not uncommon, among good writers."—Whewell, *Philosophy of the Inductive Sciences*, vol. i, p. 544 (edition of 1847).

always admitted, the polity of bees and the commonwealth of wolves fall within the purview of the biologist proper, it becomes hard to say why we should not include therein human affairs, which, in so many cases, resemble those of the bees in zealous getting, and are not without a certain parity in the proceedings of the wolves. The real fact is that we biologists are a self-sacrificing people; and inasmuch as, on a moderate estimate, there are about a quarter of a million different species of animals and plants to know about already, we feel that we have more than sufficient territory. There has been a sort of practical convention by which we give up to a different branch of science what Bacon and Hobbes would have called "Civil History." That branch of science has constituted itself under the head of Sociology. I may use phraseology which, at present, will be well understood and say that we have allowed that province of Biology to become autonomous; but I should like you to recollect that that is a sacrifice, and that you should not be surprised if it occasionally happens that you see a biologist apparently trespassing in the region of philosophy or politics; or meddling with human education; because, after all, that is a part of his kingdom which he has only voluntarily forsaken.

Having now defined the meaning of the word Biology, and having indicated the general scope of Biological Science, I turn to my second question, which is—Why should we study Biology. Possibly the time may come when that will seem a very odd question. That we, living creatures, should not feel a certain amount of interest in what it is that constitutes our life will eventually, under altered ideas of the fittest objects of human inquiry, appear to be a singular phænomenon; but at present, judging by the practice of teachers and educators, Biology would seem to be a topic that does not concern us at all. I propose to

put before you a few considerations with which I dare say many will be familiar already, but which will suffice to show—not fully, because to demonstrate this point fully would take a great many lectures—that there are some very good and substantial reasons why it may be advisable that we should know something about this branch of human learning.

I myself entirely agree with another sentiment of the philosopher of Malmesbury, "that the scope of all speculation is the performance of some action or thing to be done," and I have not any very great respect for, or interest in, mere knowing as such. I judge of the value of human pursuits by their bearing upon human interests; in other words, by their utility; but I should like that we should quite clearly understand what it is that we mean by this word "utility." In an Englishman's mouth it generally means that by which we get pudding or praise, or both. I have no doubt that is one meaning of the word utility, but it by no means includes all I mean by utility. I think that knowledge of every kind is useful in proportion as it tends to give people right ideas, which are essential to the foundation of right practice, and to remove wrong ideas, which are the no less essential foundations and fertile mothers of every description of error in practice. And inasmuch as, whatever practical people may say, this world is, after all, absolutely governed by ideas, and very often by the wildest and most hypothetical ideas, it is a matter of the very greatest importance that our theories of things, and even of things that seem a long way apart from our daily lives, should be as far as possible true, and as far as possible removed from error. It is not only in the coarser, practical sense of the word "utility," but in this higher and broader sense, that I measure the value of the study of biology by its utility; and I shall try to point out to you that you will

feel the need of some knowledge of biology at a great many turns of this present nineteenth century life of ours. For example, most of us attach great importance to the conception which we entertain of the position of man in this universe and his relation to the rest of nature. We have almost all been told, and most of us hold by the tradition, that man occupies an isolated and peculiar position in nature; that though he is in the world he is not of the world; that his relations to things about him are of a remote character; that his origin is recent, his duration likely to be short, and that he is the great central figure round which other things in this world revolve. But this is not what the biologist tells us.

At the present moment you will be kind enough to separate me from them, because it is in no way essential to my present argument that I should advocate their views. Don't suppose that I am saying this for the purpose of escaping the responsibility of their beliefs; indeed, at other times and in other places, I do not think that point has been left doubtful; but I want clearly to point out to you that for my present argument they may all be wrong; and, nevertheless, my argument will hold good. The biologists tell us that all this is an entire mistake. They turn to the physical organisation of man. They examine his whole structure, his bony frame and all that clothes it. They resolve him into the finest particles into which the microscope will enable them to break him up. They consider the performance of his various functions and activities, and they look at the manner in which he occurs on the surface of the world. Then they turn to other animals, and taking the first handy domestic animal—say a dog—they profess to be able to demonstrate that the analysis of the dog leads them, in gross, to precisely the same results as the analysis of the man; that they find almost identically the same

bones, having the same relations; that they can name the muscles of the dog by the names of the muscles of the man, and the nerves of the dog by those of the nerves of the man, and that, such structures and organs of sense as we find in the man such also we find in the dog; they analyse the brain and spinal cord and they find that the nomenclature which fits the one answers for the other. They carry their microscopic inquiries in the case of the dog as far as they can, and they find that his body is resolvable into the same elements as those of the man. Moreover, they trace back the dog's and the man's development, and they find that, at a certain stage of their existence, the two creatures are not distinguishable the one from the other; they find that the dog and his kind have a certain distribution over the surface of the world, comparable in its way to the distribution of the human species. What is true of the dog they tell us is true of all the higher animals; and they assert that they can lay down a common plan for the whole of these creatures, and regard the man and the dog, the horse and the ox as minor modifications of one great fundamental unity. Moreover, the investigations of the last three-quarters of a century have proved, they tell us, that similar inquiries, carried out through all the different kinds of animals which are met with in nature, will lead us, not in one straight series, but by many roads, step by step, gradation by gradation, from man, at the summit, to specks of animated jelly at the bottom of the series. So that the idea of Leibnitz, and of Bonnet, that animals form a great scale of being, in which there are a series of gradations from the most complicated form to the lowest and simplest; that idea though not exactly in the form in which it was propounded by those philosophers, turns out to be substantially correct. More than this, when biologists pursue their investigations into the vegetable world, they find that they can, in the

same way, follow out the structure of the plant, from the most gigantic and complicated trees down through a similar series of gradations, until they arrive at specks of animated jelly, which they are puzzled to distinguish from those specks which they reached by the animal road.

Thus, biologists have arrived at the conclusion that a fundamental uniformity of structure pervades the animal and vegetable worlds, and that plants and animals differ from one another simply as diverse modifications of the same great general plan.

Again, they tell us the same story in regard to the study of function. They admit the large and important interval which, at the present time, separates the manifestations of the mental faculties observable in the higher forms of mankind, and even in the lower forms, such as we know them, from those exhibited by other animals; but, at the same time, they tell us that the foundations, or rudiments, of almost all the faculties of man are to be met with in the lower animals; that there is a unity of mental faculty as well as of bodily structure, and that, here also, the difference is a difference of degree and not of kind. I said "almost all," for a reason. Among the many distinctions which have been drawn between the lower creatures and ourselves, there is one which is hardly ever insisted on,[1] but which may be very fitly spoken of in a place so largely devoted to Art as that in which we are assembled. It is this, that while, among various kinds of animals, it is possible to discover traces of all the other faculties of man, especially the faculty of mimicry, yet that particular form of mimicry which shows itself in the imitation of form either by modelling or by drawing, is not to be met with. As far as I know, there is no sculpture or modelling,

[1] I think that my friend, Professor Allman, was the first to draw attention to it.

and decidedly no painting or drawing, of animal origin. I mention the fact, in order that such comfort may be derived therefrom as artists may feel inclined to take.

If what the biologists tell us is true, it will be needful to get rid of our erroneous conceptions of man, and of his place in nature, and to substitute right ones for them. But it is impossible to form any judgment as to whether the biologists are right or wrong, unless we are able to appreciate the nature of the arguments which they have to offer.

One would almost think this to be a self-evident proposition. I wonder what a scholar would say to the man who should undertake to criticise a difficult passage in a Greek play, but who obviously had not acquainted himself with the rudiments of Greek grammar. And yet, before giving positive opinions about these high questions of Biology, people not only do not seem to think it necessary to be acquainted with the grammar of the subject, but they have not even mastered the alphabet. You find criticism and denunciation showered about by persons who not only have not attempted to go through the discipline necessary to enable them to be judges, but who have not even reached that stage of emergence from ignorance in which the knowledge that such a discipline is necessary dawns upon the mind. I have had to watch with some attention—in fact I have been favoured with a good deal of it myself—the sort of criticism with which biologists and biological teachings are visited. I am told every now and then that there is a "brilliant article"[1] in so-and-so, in which we are all

[1] Galileo was troubled by a sort of people whom he called "paper philosophers," because they fancied that the true reading of nature was to be detected by the collation of texts. The race is not extinct, but, as of old, brings forth its "winds of doctrine" by which the weathercock heads among us are much exercised.

demolished. I used to read these things once, but I am getting old now, and I have ceased to attend very much to this cry of "wolf." When one does read any of these productions, what one finds generally, on the face of it is, that the brilliant critic is devoid of even the elements of biological knowledge, and that his brilliancy is like the light given out by the crackling of thorns under a pot of which Solomon speaks. So far as I recollect, Solomon makes use of the image for purposes of comparison; but I will not proceed further into that matter.

Two things must be obvious: in the first place, that every man who has the interests of truth at heart must earnestly desire that every well-founded and just criticism that can be made should be made; but that, in the second place, it is essential to anybody's being able to benefit by criticism, that the critic should know what he is talking about, and be in a position to form a mental image of the facts symbolised by the words he uses. If not, it is as obvious in the case of a biological argument, as it is in that of a historical or philological discussion, that such criticism is a mere waste of time on the part of its author, and wholly undeserving of attention on the part of those who are criticised. Take it then as an illustration of the importance of biological study, that thereby alone are men able to form something like a rational conception of what constitutes valuable criticism of the teachings of biologists.[1]

Next, I may mention another bearing of biological knowledge—a more practical one in the ordinary sense of the

[1] Some critics do not even take the trouble to read. I have recently been adjured with much solemnity, to state publicly why I have "changed my opinion" as to the value of the palæontological evidence of the occurrence of evolution.

To this my reply is, Why should I, when that statement was made seven years ago? An address delivered from the Presiden-

word. Consider the theory of infectious disease. Surely that is of interest to all of us. Now the theory of infectious disease is rapidly being elucidated by biological study. It is possible to produce, from among the lower animals, examples of devastating diseases which spread in the same manner as our infectious disorders, and which are certainly and unmistakably caused by living organisms. This fact renders it possible, at any rate, that that doctrine of the causation of infectious disease which is known under the name of "the germ theory" may be well-founded; and, if so, it must needs lead to the most important practical measures in dealing with those terrible visitations. It may be well that the general, as well as the professional, public should have a sufficient knowledge of biological truths to be able to take a rational interest in the discussion of such problems, and to see, what I think they may hope to see, that, to those who possess a sufficient elementary knowledge of Biology, they are not all quite open questions.

Let me mention another important practical illustration of the value of biological study. Within the last forty years

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tial Chair of the Geological Society, in 1870, may be said to be a public document, inasmuch as it not only appeared in the *Journal* of that learned body, but was republished, in 1873, in a volume of *Critiques and Addresses*, to which my name is attached. Therein will be found a pretty full statement of my reasons for enunciating two propositions: (1) that "when we turn to the higher *Vertebrata*, the results of recent investigations, however we may sift and criticise them, seem to me to leave a clear balance in favour of the evolution of living forms one from another"; and (2) that the case of the horse is one which "will stand rigorous criticism."

Thus I did not see clearly in what way I can be said to have changed my opinion, except in the way of intensifying it, when in consequence of the accumulation of similar evidence since 1870, I recently spoke of the denial of evolution as not worth serious consideration.

the theory of agriculture has been revolutionised. The researches of Liebig, and those of our own Lawes and Gilbert, have had a bearing upon that branch of industry the importance of which cannot be over-estimated; but the whole of these new views have grown out of the better explanation of certain processes which go on in plants; and which, of course, form a part of the subject-matter of Biology.

I might go on multiplying these examples, but I see that the clock won't wait for me, and I must therefore pass to the third question to which I referred:—Granted that Biology is something worth studying, what is the best way of studying it? Here I must point out that, since Biology is a physical science, the method of studying it must needs be analogous to that which is followed in the other physical sciences. It has now long been recognised that, if a man wishes to be a chemist, it is not only necessary that he should read chemical books and attend chemical lectures, but that he should actually perform the fundamental experiments in the laboratory for himself, and thus learn exactly what the words which he finds in his books and hears from his teachers, mean. If he does not do so, he may read till the crack of doom, but he will never know much about chemistry. That is what every chemist will tell you, and the physicist will do the same for his branch of science. The great changes and improvements in physical and chemical scientific education, which have taken place of late, have all resulted from the combination of practical teaching with the reading of books and with the hearing of lectures. The same thing is true in Biology. Nobody will ever know anything about Biology except in a dilettante "paper-philosopher" way, who contents himself with reading books on botany, zoölogy, and the like; and the reason of this is simple and easy to understand.

It is that all language is merely symbolical of the things of which it treats; the more complicated the things, the more bare is the symbol, and the more its verbal definition requires to be supplemented by the information derived directly from the handling, and the seeing, and the touching of the thing symbolised:—that is really what is at the bottom of the whole matter. It is plain common sense, as all truth, in the long run, is only common sense clarified. If you want a man to be a tea merchant, you don't tell him to read books about China or about tea, but you put him into a tea-merchant's office where he has the handling, the smelling, and the tasting of tea. Without the sort of knowledge which can be gained only in this practical way, his exploits as a tea merchant will soon come to a bankrupt termination. The "paper-philosophers" are under the delusion that physical science can be mastered as literary accomplishments are acquired, but unfortunately it is not so. You may read any quantity of books, and you may be almost as ignorant as you were at starting if you don't have, at the back of your minds, the change for words in definite images which can only be acquired through the operation of your observing faculties on the phænomena of nature.

It may be said: "That is all very well, but you told us just now that there are probably something like a quarter of a million different kinds of living and extinct animals and plants, and a human life could not suffice for the examination of one-fiftieth part of all these." That is true, but then comes the great convenience of the way things are arranged; which is, that although there are these immense numbers of different kinds of living things in existence, yet they are built up, after all, upon marvellously few plans.

There are certainly more than 100,000 species of insects, and yet anybody who knows one insect—if a properly chosen

one—will be able to have a very fair conception of the structure of the whole. I do not mean to say he will know that structure thoroughly, or as well as it is desirable he should know it; but he will have enough real knowledge to enable him to understand what he reads, to have genuine images in his mind of those structures which become so variously modified in all the forms of insects he has not seen. In fact, there are such things as types of form among animals and vegetables, and for the purpose of getting a definite knowledge of what constitutes the leading modifications of animal and plant life, it is not needful to examine more than a comparatively small number of animals and plants.

Let me tell you what we do in the biological laboratory which is lodged in a building adjacent to this. There I lecture to a class of students daily for about four-and-a-half months, and my class have, of course, their text-books; but the essential part of the whole teaching, and that which I regard as really the most important part of it, is a laboratory for practical work, which is simply a room with all the appliances needed for ordinary dissection. We have tables properly arranged in regard to light, microscopes, and dissecting instruments, and we work through the structure of a certain number of animals and plants. As, for example, among the plants, we take a yeast plant, a *Protococcus,* a common mould, a *Chara,* a fern, and some flowering plant; among animals we examine such things as an *Amœba,* a *Vorticella,* and a fresh-water polype. We dissect a star-fish, an earth-worm, a snail, a squid, and a fresh-water mussel. We examine a lobster and a cray-fish, and a black beetle. We go on to a common skate, a cod-fish, a frog, a tortoise, a pigeon, and a rabbit, and that takes us about all the time we have to give. The purpose of this course is not to make skilled dissectors, but to give every student a

clear and definite conception, by means of sense-images, of the characteristic structure of each of the leading modifications of the animal kingdom; and that is perfectly possible, by going no further than the length of that list of forms which I have enumerated. If a man knows the structure of the animals I have mentioned, he has a clear and exact, however limited, apprehension of the essential features of the organisation of all those great divisions of the animal and vegetable kingdoms to which the forms I have mentioned severally belong. And it then becomes possible for him to read with profit; because every time he meets with the name of a structure, he has a definite image in his mind of what the name means in the particular creature he is reading about, and therefore the reading is not mere reading. It is not mere repetition of words; but every term employed in the description, we will say, of a horse, or of an elephant, will call up the image of the things he had seen in the rabbit, and he is able to form a distinct conception of that which he has not seen, as a modification of that which he has seen.

I find this system to yield excellent results; and I have no hesitation whatever in saying, that any one who has gone through such a course, attentively, is in a better position to form a conception of the great truths of Biology, especially of morphology (which is what we chiefly deal with), than if he had merely read all the books on that topic put together.

The connection of this discourse with the Loan Collection of Scientific Apparatus arises out of the exhibition in that collection of certain aids to our laboratory work. Such of you as have visited that very interesting collection may have noticed a series of diagrams and of preparations illustrating the structure of a frog. Those diagrams and preparations have been made for the use of the students in the

biological laboratory. Similar diagrams and preparations illustrating the structure of all the other forms of life we examine, are either made or in course of preparation. Thus the student has before him, first, a picture of the structure he ought to see; secondly, the structure itself worked out; and if with these aids, and such needful explanations and practical hints as a demonstrator can supply, he cannot make out the facts for himself in the materials supplied to him, he had better take to some other pursuit than that of biological science.

I should have been glad to have said a few words about the use of museums in the study of Biology, but I see that my time is becoming short, and I have yet another question to answer. Nevertheless, I must, at the risk of wearying you, say a word or two upon the important subject of museums. Without doubt there are no helps to the study of Biology, or rather to some branches of it, which are, or may be, more important than natural history museums; but, in order to take this place in regard to Biology, they must be museums of the future. The museums of the present do not, by any means, do so much for us as they might do. I do not wish to particularise, but I dare say many of you, seeking knowledge, or in the laudable desire to employ a holiday usefully, have visited some great natural history museum. You have walked through a quarter of a mile of animals, more or less well stuffed, with their long names written out underneath them; and, unless your experience is very different from that of most people, the upshot of it all is that you leave that splendid pile with sore feet, a bad headache, and a general idea that the animal kingdom is a "mighty maze without a plan." I do not think that a museum which brings about this result does all that may be reasonably expected from such an institution. What is needed in a collection of natural history is that it

should be made as accessible and as useful as possible, on the one hand to the general public, and on the other to scientific workers. That need is not met by constructing a sort of happy hunting-ground of miles of glass cases; and, under the pretence of exhibiting everything putting the maximum amount of obstacle in the way of those who wish properly to see anything.

What the public want is easy and unhindered access to such a collection as they can understand and appreciate; and what the men of science want is similar access to the materials of science. To this end the vast mass of objects of natural history should be divided into two parts—one open to the public, the other to men of science, every day. The former division should exemplify all the more important and interesting forms of life. Explanatory tablets should be attached to them, and catalogues containing clearly-written popular expositions of the general significance of the objects exhibited should be provided. The latter should contain, packed into a comparatively small space, in rooms adapted for working purposes, the objects of purely scientific interest. For example, we will say I am an ornithologist. I go to examine a collection of birds. It is a positive nuisance to have them stuffed. It is not only sheer waste, but I have to reckon with the ideas of the bird-stuffer, while, if I have the skin and nobody has interfered with it, I can form my own judgment as to what the bird was like. For ornithological purposes, what is needed is not glass cases full of stuffed birds on perches, but convenient drawers into each of which a great quantity of skins will go. They occupy no great space and do not require any expenditure beyond their original cost. But for the edification of the public, who want to learn indeed, but do not seek for minute and technical knowledge, the case is different. What one of the general public walking

into a collection of birds desires to see is not all the birds that can be got together. He does not want to compare a hundred species of the sparrow tribe side by side; but he wishes to know what a bird is, and what are the great modifications of bird structure, and to be able to get at that knowledge easily. What will best serve his purpose is a comparatively small number of birds carefully selected, and artistically, as well as accurately, set up; with their different ages, their nests, their young, their eggs, and their skeletons side by side; and in accordance with the admirable plan which is pursued in this museum, a tablet, telling the spectator in legible characters what they are and what they mean. For the instruction and recreation of the public such a typical collection would be of far greater value than any many-acred imitation of Noah's ark.

Lastly comes the question as to when biological study may best be pursued. I do not see any valid reason why it should not be made, to a certain extent, a part of ordinary school training. I have long advocated this view, and I am perfectly certain that it can be carried out with ease, and not only with ease, but with very considerable profit to those who are taught; but then such instruction must be adapted to the minds and needs of the scholars. They used to have a very odd way of teaching the classical languages when I was a boy. The first task set you was to learn the rules of the Latin grammar in the Latin language—that being the language you were going to learn! I thought then that this was an odd way of learning a language, but did not venture to rebel against the judgment of my superiors. Now, perhaps, I am not so modest as I was then, and I allow myself to think that it was a very absurd fashion. But it would be no less absurd, if we were to set about teaching Biology by putting into

the hands of boys a series of definitions of the classes and orders of the animal kingdom, and making them repeat them by heart. That is so very favourite a method of teaching, that I sometimes fancy the spirit of the old classical system has entered into the new scientific system, in which case I would much rather that any pretence at scientific teaching were abolished altogether. What really has to be done is to get into the young mind some notion of what animal and vegetable life is. In this matter, you have to consider practical convenience as well as other things. There are difficulties in the way of a lot of boys making messes with slugs and snails; it might not work in practice. But there is a very convenient and handy animal which everybody has at hand, and that is himself; and it is a very easy and simple matter to obtain common plants. Hence the general truths of anatomy and physiology can be taught to young people in a very real fashion by dealing with the broad facts of human structure. Such viscera as they cannot very well examine in themselves, such as hearts, lungs, and livers, may be obtained from the nearest butcher's shop. In respect to teaching something about the biology of plants, there is no practical difficulty, because almost any of the common plants will do, and plants do not make a mess—at least they do not make an unpleasant mess; so that, in my judgment, the best form of Biology for teaching to very young people is elementary human physiology on the one hand, and the elements of botany on the other; beyond that I do not think it will be feasible to advance for some time to come. But then I see no reason, why, in secondary schools, and in the Science Classes which are under the control of the Science and Art Department—and which I may say, in passing, have in my judgment, done so very much for the diffusion of a knowledge of science over the country—we

should not hope to see instruction in the elements of Biology carried out, not perhaps to the same extent, but still upon somewhat the same principle as here. There is no difficulty, when you have to deal with students of the ages of fifteen or sixteen, in practising a little dissection and in getting a notion of, at any rate, the four or five great modifications of the animal form; and the like is true in regard to the higher anatomy of plants.

While, lastly, to all those who are studying biological science with a view to their own edification merely, or with the intention of becoming zoölogists or botanists to all those who intend to pursue physiology—and especially to those who propose to employ the working years of their lives in the practice of medicine—I say that there is no training so fitted, or which may be of such important service to them, as the discipline in practical biological work which I have sketched out as being pursued in the laboratory hard by.

I may add that, beyond all these different classes of persons who may profit by the study of Biology, there is yet one other. I remember, a number of years ago, that a gentleman who was a vehement opponent of Mr. Darwin's views and had written some terrible articles against them, applied to me to know what was the best way in which he could acquaint himself with the strongest arguments in favour of evolution. I wrote back, in all good faith and simplicity, recommending him to go through a course of comparative anatomy and physiology, and then to study development. I am sorry to say he was very much displeased, as people often are with good advice. Notwithstanding this discouraging result, I venture, as a parting word, to repeat the suggestion, and to say to all the more

or less acute lay and clerical "paper-philosophers"[1] who venture into the regions of biological controversy—Get a little sound, thorough, practical, elementary instruction in biology.

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[1] Writers of this stamp are fond of talking about the Baconian method. I beg them therefore to lay to heart these two weighty sayings of the herald of Modern Science:—

"Syllogismus ex propositionibus constat, propositiones ex verbis, verba notionum tesseræ sunt. Itaque si notiones ipsæ (*id quod basis rei est*) confusæ sint et temere a rebus abstractæ, nihil in iis quæ superstruuntur est firmitudinis."—*Novum Organon*, ii., 14.

"Huic autem vanitati nonnulli ex modernis summa levitate ita indulserunt, ut in primo capitulo Geneseos et in libro Job et aliis scripturis sacris, philosophiam naturalem fundare conhei sint; *inter vivos quærentes mortua*."—*Ibid.*, 65.

NOTES

I. AUTOBIOGRAPHY

2:6. **Bishop Butler.** Joseph Butler (1692–1752), Bishop of Durham. He was perhaps the man of greatest intellectual power in the Church of England during the eighteenth century, and wrote the best defense of revealed religion of his age. He was made Bishop of Durham two years before his death, and expended much money in repairing his church and residence.

2:10. **Auckland.** Called *Bishop Auckland* because the Bishop's palace, "the episcopal seat," is in the neighborhood. A town in the county of Durham, England.

2:11. **apologist.** Defender of Christianity.

2:17. **pre-Boswellian.** James Boswell (1740–1795), the friend and biographer of Samuel Johnson. In his essay on Johnson, Macaulay says: "Homer is not more decidedly the first of heroic poets, Shakespeare is not more decidedly the first of dramatists, Demosthenes is not more decidedly the first of orators, than Boswell is the first of biographers." Boswell's *Life* is the first of the intensely intimate kind, of which we have since had many examples. *The Life and Letters of Thomas Henry Huxley*, by his son Leonard, is one of this type.

2:22. **"Bene qui latuit, bene vixit."** Ovid. He who has concealed himself well, has lived well—"not in the public eye."

3:3. **some years ago.** See Prefatory Note.

3:9. **Hyde Park Corner.** The most used of the nine gateways to Hyde Park. It was built in 1828.

3:19. See Smith's Classical Dictionary, Life of Plato. The tradition is that soon after Plato's birth bees lighted on his lips, while he was asleep, and deposited honey.

5:3. **Prince George of Cambridge.** George William Frederick Charles, second Duke of Cambridge (1819–1904). His father was

the youngest son of George III. He was made Commander-in-chief of the British army in 1856; he retired in 1895.

5:10. Mr. Herbert Spencer (1820–1903). Perhaps the most famous English philosopher of the nineteenth century. He applied Darwin's ideas of struggle for existence and survival of the fittest in the physical world to the economic life of man. He was a close friend of both Darwin and Huxley.

5:14. all sorts and conditions of men. The title of a novel by Sir Walter Besant much talked about at the time Huxley wrote his *Autobiography.* It led to the building of the People's Palace in the east end of London, an institution for the amusement and instruction of the working men in that section of the city.

5:21. struggle for existence. This phrase was used by Darwin as early as 1838. It meant the struggle of plants and animals to overcome unfavorable conditions in their surroundings, in their effort to survive. Tennyson suggests the same idea when he speaks of "Nature red in tooth and claw." (*In Memoriam.*)

6:13–14. a medical brother-in-law. Two of Huxley's sisters married physicians—Dr. Cooke and Dr. Scott. Dr. Cooke of Coventry is here meant.

6:17. in partibus infidelium: in the domain of the unfaithful.

7:18. "sweet south upon a bed of violets." Cf. "Twelfth Night," I, i, 5:

> "O! it came o'er my ear like the sweet sound
> That breathes upon a bank of violets
> Stealing and giving odor."

This is the reading of the first Folio and early editions. Pope changed *sound* to *south*, which according to Hudson is the correct reading, though Knight and Rolfe hold to the original.

8:3. Mr. Wharton Jones. Says Mr. Leonard Huxley in his *Life* of Thomas Henry Huxley: "He never forgot his debt to Wharton Jones, and years afterwards was delighted at being able to do him a good turn by helping to obtain a pension for him."

8:23. Sir Joseph Fayrer (1824–1907). He was made physician extraordinary to King Edward VII in 1901.

9:15. Haslar Hospital. The chief establishment in Great Britain for invalid sailors, of whom 2,000 can be accommodated and supplied with medical attendance at once. It is in Gosport,

a seaport on the west shore of Portsmouth harbor, directly opposite Portsmouth, with which it is connected by a floating bridge.

9:19. **Sir John Richardson** (1787–1865). A British naturalist and arctic explorer.

10:25. **Sir Andrew Clark** (1826–1893). An eminent Scotch physician who resided in London.

11:17. **Buffon** (1707–1788). An eminent French naturalist. To him we owe the celebrated phrase, "The style is the man." *Suites à Buffon, formant avec les œuvres de cet auteur un cours complet d'histoire naturelle.* A series of monographs, edited by Roret from 1834–1857 at Paris, for his *Libraire Encyclopedique* (Encyclopedia), forming with the works of Buffon a complete natural history.

11:21. **Linnean Society.** A scientific society of London named from Linnæus (1707–1778), the Swedish botanist. It was founded in 1788 by James Edward Smith.

11:22–23. **Noah when he sent the raven out of his ark.** Cf. Genesis VIII, 7, 8.

7. "And he sent forth a raven, which went forth to and fro, until the waters were dried up from off the earth."

8. "Also he sent forth a dove from him, to see if the waters were abated from off the face of the ground."

11:24. **to do or die.** Cf. Burns's *Bannockburn*, last stanza.

> "Lay the proud usurpers low!
> Tyrants fall in every foe!
> Liberty's in every blow!
> Let us do or die!"

11:26. **Royal Society.** Founded in 1660, incorporated by Charles II in 1662. See account of its foundation in the essay, *On the Adviseableness of Improving Natural Knowledge* (pp. 41–44).

12:9. **Père Goriot,** "the modern King Lear," a novel by Balzac.

12:10. **"à nous deux":** *maintenant, à nous deux:* now, it is a question between us—now, we will settle it—warfare declared.

12:13. **Professor Tyndall.** John Tyndall (1820–1893), a distinguished British physicist. He was Professor of Natural History at the Royal Institution and fellow of the Royal Society. An intimate friend of Huxley, with whom he did much scientific work.

12:23. Sir Henry de la Beche (1796–1855). An English geologist.

13:3. Royal Institution. Founded in 1799 by Count Rumford and other noblemen. It was incorporated by George III January 13, 1800, as "The Royal Institution of Great Britain," for diffusing knowledge and facilitating the general introduction of useful mechanical inventions and improvements, and for teaching, by courses of philosophical lectures and experiments, the application of science to the common purposes of life.—Harper's Book of Facts.

13:4. malgré moi: in spite of myself.

14:4. ecclesiastical spirit. In his long fight for freedom of thought, Huxley's attack was not on religion but on that clericalism, that ecclesiasticism which denounced every person and every thought connected with evolution. He says: "The antagonism of science is not to religion but to the heathen survivals and the bad philosophy under which religion herself is often well-nigh crushed."

II. ON THE EDUCATIONAL VALUE OF THE NATURAL HISTORY SCIENCES

17:23. Newton, Sir Isaac (1642–1727). A famous English mathematician. He discovered the law of gravitation; was a fellow and afterwards President of the Royal Society. His great work, *Principia*—full title *Philosophiæ Naturalis Principia Mathematica* (The Mathematical Principles of Natural Philosophy)—is the foundation of modern astronomy, mechanics, and mathematics. It was written in Latin and presented to the Royal Society in 1686.

21:30. the Inquisition. During the Middle Ages, a court in the Roman Catholic Church for the suppression of heresy through the punishment of heretics. The Spanish Inquisition was put under the control of the state at the end of the fifteenth century, and became notorious for the number of its victims. The proceedings were secret. Its influence diminished during the eighteenth century and it was finally suppressed in 1834.

22:15. Cuvier (1769–1832). A French naturalist. His two great works, *Lessons in Comparative Anatomy* and *The Animal Kingdom*, place him in the first rank of the world's naturalists.

He made exhaustive studies of the fossils found in the Paris basin, especially in the hill of Montmartre, now one of the quarters of the city. He could reconstruct the whole animal from the inspection of a single fossil bone. For an interesting account of how he did this, see Huxley's essay *On the Method of Zadig.*

22:21. **Adams,** John Couch (1819–1892). An English astronomer. He shares with Leverrier the honor of the discovery of Neptune in 1846.

Leverrier (1811–1877). A noted French astronomer; became Director of the Paris Observatory in 1854.

22:29. **M. Jourdain.** A character in Molière's *Le bourgeoise gentilhomme* (The Citizen Gentleman). He is a plain citizen who aspires to be the fine gentleman, and to that end educates himself and family. His astonishment at the discovery that he has been talking prose all his life has passed into a proverb.

24:28. **M. Comte** (1798–1857). A noted French philosopher. In his great work, *Positive Philosophy,* he classifies the history of thought into three stages: the theological, the metaphysical, and the positive or scientific.

Miss Martineau. Harriet Martineau (1802–1876). A gifted English author interested in political science and philosophy. She wrote a series of stories illustrating the political economy of the time and translated the works of M. Comte for English readers.

25:5. **Harvey,** William (1578–1657). A celebrated English physician and physiologist; the discoverer of the circulation of the blood.

25:6. **Sir Charles Bell** (1774–1842). A distinguished English physiologist; noted for the discovery of the distinct functions of the sensory and motor nerves.

25:22. **Bernard,** Claude (1813–1878). A noted French physiologist.

26:34. **Whewell,** William (1794–1866). A celebrated English scientist and philosopher.

29:32–33. **à priori:** before experience.

31:6. **Laplace** (1749–1827). A celebrated French astronomer and mathematician.

Jardin des Plantes (Botanical Garden). This is really an Institution of Natural History. It consists of two parts: the Botanical Gardens and the Zoölogical Park, and within its inclosure is a natural history museum, a public library, and lecture

rooms. It dates back to Louis XIII (1626), and became the most famous institution of its kind in all Europe when Buffon was made director in 1739.

31:7. Observatory. The famous Paris observatory was erected between the years 1667–1672. Some of the greatest astronomical discoveries have been made here.

31:33. Mr. John Stuart Mill (1806–1873). A celebrated English logician and political economist. His *Logic* and his *Political Economy* are great books of their kind.

32:23. "To point a moral, or adorn a tale." Dr. Johnson, *Vanity of Human Wishes*, Line 221.

34:21. phreno-magnetism. The power of exciting the brain by magnetic or mesmeric influence.

35:24. Manichean doctrine. The doctrine of Manes, a Persian prophet of the third century, A.D. He taught that life is a conflict between Light, the source of Good, and Darkness, the source of Evil; that only through strictest self-denial can one overcome the evil which he believed to be inherent in matter.

35:34. Peter Bell. A poem by Wordsworth.

36:1. "A primrose by the river's brim," etc. In Part I, stanza 12, of *Peter Bell*. The entire stanza reads:

> "In vain through every changeful year,
> Did nature lead him as before;
> A primrose by a river's brim
> A yellow primrose was to him,
> And it was nothing more."

36:20. "wept when they might be joyful." Cf. Dante. *Inferno*, Canto XI, Line 45. Longfellow's Translation.

> "And weepeth there, where he should jocund be."

(In the second round of the seventh circle, where the violent are punished. Canto XI gives a general description of the Inferno and its divisions.)

III. ON THE ADVISEABLENESS OF IMPROVING NATURAL KNOWLEDGE

39:6. the very spot. St. Martin's Hall, in Long Acre Street, near Drury Lane. It was originally built for Hullah's popular concerts (1850). It was burned down, but a new hall was

erected on its site in 1861. Charles Dickens gave many of his early readings there, and many other eminent men made appearances there. It is now occupied by James Spicer and Sons, paper makers, and by the Agricultural and Horticultural Associations, Limited, the buildings having been adapted to their needs.

Defoe, in his *Journal of the Plague Year*, paragraph 2, tells us that in "the latter end of November, or the beginning of December, 1664, . . . two men, said to be Frenchmen, died of the plague in Long Acre, or rather at the upper end of Drury Lane."

39:13–14. **"The History of the Plague Year."** Defoe's *Journal of the Plague Year* is a marvelous piece of realistic fiction. It reads like the report of an eyewitness. Daniel Defoe (1661–1731) produced all his works of fiction, the best known of which is *Robinson Crusoe*, after he was sixty years old.

41:6–7. **the crackling wit of the Rochesters and Sedleys.** John Wilmot, Earl of Rochester, courtier and poet of the reign of Charles II. Sir Charles Sedley, a wit, poet, and dramatist of the Restoration. He justified himself for the part he took in the Revolution by saying: "As James II had made his (Sedley's) daughter a countess, he could do no less than endeavor to make his (James's) daughter a queen." These men are typical courtiers of their time.

41:11. **Laud,** William (1573–1645). Archbishop of Canterbury, supporter of Charles I. He was impeached by the Long Parliament and executed, 1645.

Milton, John (1608–1674). The great English poet, author of *Paradise Lost*. He joined in the attack on the English Church during the Civil War against Charles I. He became Latin Secretary under Cromwell and wrote many political pamphlets for the government, among which was his *Defence of the English People*. He was an ardent advocate of freedom of speech and of religious independence. "The faith of Laud or that of Milton"—the English Church or Puritanism.

41:34. **Copernican hypothesis.** Copernicus (1473–1543) was the founder of modern astronomy. His hypothesis that the sun was the center of the universe displaced the old Ptolemaic theory that the sun, the planets, and the stars revolved around the earth.

42:4. **selonography.** The scientific study of the moon.

42:8. **Torricellian experiment.** Torricelli (1608–1647) dis-

covered the principle of the barometer and improved the microscope.

42:14. Galileo (1564–1642). A famous Italian astronomer and physician. He constructed a thermometer and a telescope; discovered Jupiter's satellites and the sun's spots. He was summoned to Rome when his doctrines were condemned by the Pope, and he was forced to give up the Copernican theory by the Inquisition. The story is told that, after he had retracted his statement about the earth's revolution around the sun, he said, "Nevertheless it does move." This is declared by modern critics to be a myth.

42:15. Sir Francis Bacon (1561–1626). A celebrated English philosopher, statesman, and writer. His fame rests on his services as a reformer of the methods of scientific investigation. Though his work has been exaggerated, he may be considered one of the founders of modern inductive science. This is the New Philosophy. His chief works are *The Advancement of Learning*, published in English, and *Novum Organum*, written in Latin. As a literary figure his fame rests on his Essays.

42:19. The learned Dr. Wallis. John Wallis (1616–1703), an English mathematician, logician, and grammarian.

42:21–22. Dr. Wilkins (1614–1672), a famous English bishop and scientist. His works, more than those of any other one man, helped spread the Copernican theory in England. He was one of the founders of the Royal Society.

42:33. Chelsea College. Chelsea College was founded by James I "for the defence of the true religion established within the realm." But the institution was not supported by the English Church and fell into decay. In 1664 the Royal Society sent a petition to King Charles II "to grant Chelsea College and the lands belonging to it to the Royal Society." The King agreed and the patent, granting Chelsea College and lands, about thirty acres, was signed April 8, 1669. It was a splendid gift for those days. The Society tried to rent it as a war prison but without success, because of its dilapidated condition, and finally sold it to the Government in 1682 for £1,300. Charles II built the Royal Hospital for Soldiers on its site.—Weld, Charles R. *A History of the Royal Society*, 2 vols.

The Royal Society met in Gresham College from 1660 till 1710, with the exception of a short interval after the Great Fire. It now meets in a building erected in 1872 in the gardens of Old

Burlington House, which was purchased by the Government in 1854.

43:13–14. **Newton—Principia.** (See note to p. 17, line 23, *On the Educational Value of the Natural History Sciences.*)

43:15. **"Philosophical Transactions."** The principal publications of the Royal Society are *The Philosophical Transactions*, begun in 1665, and *The Proceedings of the Royal Society*, begun in 1800.

43:33. **Vesalius** (1514–1564). A Belgian anatomist. He lived in Madrid and was condemned to death by the Inquisition, but his sentence was commuted by the King to a pilgrimage to the Holy Sepulchre. On his return voyage he was shipwrecked.

Harvey. (See note to p. 25, line 5, *On the Educational Value of the Natural History Sciences.*)

43:34. **their grain of mustard seed.** Cf. Matthew XIII, 31. " . . . The kingdom of heaven is like to a grain of mustard seed, which a man took, and sowed in his field: " also Mark IV, 31, 32.

31. "It [the kingdom of heaven] is like a grain of mustard seed, which, when it is sown in the earth, is less than all the seeds that be in the earth:

32. "But when it is sown, it groweth up, and becometh greater than all herbs, and shooteth out great branches; so that the fowls of the air may lodge under the shadow of it."

44:10. **Schoolmen.** The name given to the philosophers of the Middle Ages because they taught in the schools—universities. They spent their time spinning fine arguments about abstract ideas of no use to any one. Their speculations were far removed from the real experiences of life.

44:16. **"writ in water."** "Here lies one whose name is writ in water." The epitaph on Keats's tombstone in the Protestant Cemetery at Rome, composed by the poet himself.

44:24. **Lord Brouncker.** President of the Royal Society after its incorporation, July 15, 1662. Sir Robert Moray was President from March 6, 1661, till its incorporation.

45:2. **revenant.** Specter, ghost.

45:15. **Mr. Hooke.** Robert Hooke (1635–1703), "the first curator and experimenter" of the Royal Society. An English natural philosopher.

45:32. **Boyle,** Robert (1627–1691). A British chemist; he discovered what is known as Boyle's law of the elasticity of the air.

45:32. Evelyn, John (1620–1706). A Royalist in favor at the court of Charles II. He was Secretary of the Royal Society in 1672. His diary is one of the interesting source books of the seventeenth century.

46:1. the Restoration. The reëstablishment of the English monarchy with the coronation of Charles II in 1660.

48:15. blind leaders of the blind. Cf. Matthew XV, 14. "Let them alone: they be blind leaders of the blind. And if the blind lead the blind, both shall fall into the ditch."

48:28–29. Aladdin's lamps. The source of wealth and power. Aladdin, in the *Arabian Nights*, obtains a magic lamp and has a splendid palace built by the genius of the lamp. He marries the daughter of the Sultan of China, loses his lamp, and his palace is transported to Africa.

48:30–31. thank God they are better than their benighted ancestors. Cf. Luke XVIII, 11.

"The Pharisee stood and prayed thus with himself, God, I thank thee, that I am not as other men are" . . .

50:14. "When in heaven the stars about the moon look beautiful," etc.—Tennyson. *Specimen of a Translation of the Iliad in Blank Verse*, Line 11.

51:12. Fetish (usually spelled fetich). A fetich is anything in nature or art—a stone, a carved image, a part of a plant or an animal—to which magical or supernatural power is ascribed. It was supposed by certain African tribes that the possession of a fetich gave the owner power to control the supernatural being which it represented.

52:1. "increasing God's honour and bettering man's estate." Cf. Bacon, *The Advancement of Learning*. Men should seek knowledge, Bacon tells us, "For the glory of the Creator and the relief of man's estate."

53:17. Count Rumford, Benjamin Thompson (1753–1814). An American scientist, educated at Harvard. He was refused a commission in the Continental army, so went over to the British. He was elected a fellow of the Royal Society in 1779; suggested the plan and assisted in the foundation of the Royal Institution in 1799. He went to Bavaria, where he reorganized the military establishment. He spent the latter part of his life in Paris. He gave $5,000 to the American Academy of Arts and Sciences, and the same amount to the Royal Society of London to found prizes bearing his name for the most important discoveries in heat and

light, and he left to Harvard the funds with which the Rumford professorship has been established.

55:2–3. **by worship "for the most part of the silent sort."**

Cf. "The heart ran o'er
With silent worship of the great of old."
—Lord Byron, *Manfred*, Act III, Sc. IV.

IV. A LIBERAL EDUCATION: AND WHERE TO FIND IT

59:29. **Ichabod! Ichabod!** Cf. I Samuel IV, 21. "And she named the child Ichabod, saying, The Glory is departed from Israel."

60:3. **the people perish for lack of knowledge.** Cf. Hosea IV, 6. "My people are destroyed for lack of knowledge."

61:22. **a senior wranglership.** A wrangler is one who has obtained a place in the highest mathematical honor-class; the first man of this class is termed *senior wrangler*. The term is in use at Cambridge University.

double-first (Oxford University). A degree of the first class in both the classics and mathematics.

63:12. **gambit.** A mode of opening the game of chess, in which a pawn is sacrificed to gain an attacking position.

64:2. **without haste, but without remorse.** An adaptation of Huxley's favorite phrase from Goethe. "Ohne Hast, Aber ohne Rast" (without haste, but without rest). Goethe's *Zahme Xenien*, II.

64:4. **Retzsch** (1779–1857). A German etcher and painter. He illustrated the works of Goethe and Schiller.

65: 23. **Nature having no Test-Acts.** The Test-Act directed all officers, civil and military, under the government to receive the sacrament according to the form of the English Church. Enacted in 1673; repealed in 1828. The University Test-Acts in 1871 abolished all subscriptions to the articles of the Church of England, all declarations and oaths respecting religious belief, and all compulsory attendance at public worship in the universities of Oxford, Cambridge, and Durham. To be a member of the Church of England was a necessary condition precedent for holding most university or college offices by the Act of Uniformity, 1662, and such offices were not affected by the Toleration Act of 1689, or the Roman Catholic Relief Act of 1829.

65:27. **the "Poll."** To go out in the poll. To take an ordinary degree—a degree without university "honors."

65:29. **plucked.** To pluck is to reject a candidate for literary honors because he is not up to the required mark. The rejected candidate is said to be *plucked.*

67:33. **the hundred.** In southern and central England the division or subdivision of a county. It was the basis for the organization of the military and fiscal systems. The origin of the territorial hundred is uncertain. Some find it in the division of a hundred hides of land (a hide in old English law was as much land as would support one family); others find it in groups of a hundred families.

68:13 **Falstaff's bill,** etc. Cf. I Henry IV, II, iv, 550. Prince Henry.—"O monstrous! but one half-pennyworth of bread to this intolerable deal of sack!"

69:11. **circumbendibus.** Jocular for circumlocution, a roundabout method of speech. Cf. Coleridge, *Table Talk,* Jan. 4, 1823. "A rogue is a roundabout fool; a fool *in circumbendibus.*"

71:29. **Euclid.** A famous Greek geometer of the fourth century B.C. His *Elements* has been used as a text-book down to the present time.

72:19. **Chaucer,** Geoffrey (1340–1400). The first great English poet. His most famous work, *The Canterbury Tales,* is familiar to most high school students.

Shakespeare, William (1564–1616). The greatest of all dramatists.

72:20. **Milton.** (See note to p. 41, line 11, *On the Adviseableness of Improving Natural Knowledge.*)

Voltaire (1694–1778). A famous French writer of plays, history, and fiction.

Goethe (1749–1832). The most famous of all German authors. His tragedy, *Faust,* is world-renowned. Besides being a dramatist, he was a prose writer and a great lyric poet.

Schiller (1759–1805). Next to Goethe, the most famous name in German literary history. He wrote many dramas, some of which are familiar to English readers in translation: *Mary Stuart, Joan of Arc,* etc. He and Goethe were close friends.

73:27–28. **Tasmania.** An island and British colony south of Australia.

73:27–28. New South Wales. A state of the Commonwealth of Australia. Look up on the map.

74:2. Croesus. A King of Lydia, sixth century B.C.; famed for his great riches.

75:21. Niebuhr. Niebuhr, Barthold Georg (1776–1831), the great German historian. His *Römische Geschichte* (Roman History, 3 vols.) produced a revolution in the method of historical study.

Gibbon, Edward (1737–1794), the famous English historian of the Roman Empire. His *Decline and Fall of the Roman Empire* is still the chief authority on the period it covers.

Grote, George (1794–1841). A celebrated English historian; his great work is a *History of Greece.*

76: 30. Cicero. A celebrated Roman orator and statesman, first century B.C. He took an active part in the political intrigues of his day, delivered the Philippics against Antony, was proscribed by the second Triumvirate, and slain in 43 B.C.

76:31. Horace. A famous Roman satirical poet, first century B.C.

form. A class or rank of students in a school. (Used in England.)

76:32. Terence. A celebrated Roman comic poet, second century B.C.

77:13. Parnassus. A mountain of Phocis in Greece, sacred to Apollo and the Muses. The region of poetry. To climb Parnassus is to write poetry.

78:8. These be your gods, O Israel! Cf. Exodus XXXII, 3, 4.

3. "And all the people brake off the golden earrings which were in their ears, and brought them unto Aaron.

4. . . . "And they said, These be thy gods, O Israel, which brought thee up out of the land of Egypt."

78:13–14. the stone he offers . . . to feed with bread. Cf. Matthew VII, 9, "Or what man is there of you, whom if his son ask bread, will he give him a stone?"

78:16–17. This is an awful subject. Cf. Burke. Introduction to Speech on Conciliation with America.

78:20. Rector of Lincoln College. See note below, p. 79, line 10.

78:25. faculties. The learned professions.

79:10. Pattison, Mark (1813–1884). An English writer and

educator. He graduated at Oxford, became fellow and afterwards tutor and rector at Lincoln College, Oxford University.

80:33. **Grote.** (See note above to p. 75: 21.)

80:34. **Mill.** (See note to p. 31, line 33, *On the Educational Value of the Natural History Sciences.*)

Faraday, Michael (1791–1867). An English physicist and chemist. Professor of Chemistry in the Royal Institution, 1833. He made many discoveries in electricity and magnetism.

Brown, Robert (1773–1858). A botanist; keeper of the botanical department of the British Museum after 1827.

Lyell, Sir Charles (1797–1875). A celebrated English geologist. President of the Royal Society. He visited the United States and wrote a charming book of travels after his return. His well-known works are *Principles of Geology* and *The Antiquity of Man.*

81:1. **Darwin,** Charles (1809–1882). The propounder of the theory of evolution, though Alfred Russell Wallace discovered the principle at the same time. The epoch-making book, in which he gave to the world his views, was *The Origin of Species,* published in 1859.

82:15–16. **la carrière ouverte aux talents.** A career is open to talent.

82:16. **Bursch.** Fellow; here, student at the university.

83:34. **"Erdkunde."** Earth-knowledge; geography.

V. ON A PIECE OF CHALK

86–87:2–6. **Norwich—shores of Kent.** Trace on the map on p. 201 the distribution of chalk indicated in this paragraph.

87:8. **Albion.** From the same root as the Gaelic *Alp,* literally, "the white land." The name bestowed on the land lying behind the white cliffs of southern England, visible from the coast of Gaul.

87:11–12. **diagonally across England from Lulworth in Dorset,** etc. Trace on the map. At Osmington, near Lulworth, is an equestrian statue of George III. cut in the chalk. Baedeker's *Great Britain.*

87:16. **Weald of Kent and Sussex.** Weald (woods). *Wealden formation* is the name given to a formation deposited in an inland sea which once covered much of southern England, because it

was first studied in the parts of Kent, Surrey, and Sussex called the *Weald*. It consists of Weald clay, 560 feet; and Hastings sand, 740 feet; total, 1,300 feet.

87:30. **Crimea.** A peninsula in southern Russia, nearly surrounded by the Black Sea and the Sea of Azoff.

Syria. A country in Asiatic Turkey extending from the Mediterranean eastward to the Euphrates, and from Egypt northward to about latitude 36° N.

87:31. **Sea of Aral.** An inland sea of Russian Central Asia.

88:8. **rounded coombs.** Coomb, a more or less rounded, bowl-shaped hollow valley, inclosed on all sides but one by steep cliffs.

88:18. **the Lebanon.** (Hebrew, the white.) The lofty mountain range in the southern part of Syria.

89:6. I weigh my words well, etc. Compare with this thought Tennyson's "Flower in the crannied wall."

> "Flower in the crannied wall,
> I pluck you out of the crannies,
> I hold you here, root and all, in my hand,
> Little flower—but *if* I could understand
> What you are, root and all, and all in all
> I should know what God and man is."

90:7. stalagmites-stalactites. Deposits of calcium carbonate found in caves; stalactites, cone-like in shape, hanging from the roof, and stalagmites, inverted cones, rising from the floor of the cavern.

90:21. laminated mineral substance. A substance consisting of layers or scales.

90:26. matrix. The earthy or stony substance in which metallic ores or crystals are found.

91:15. Globigerina. (Pronounced glō̇-bĭj′ē̇-rī′nȧ.)

93:16. Lieut. Brooke. John Mercer Brooke (1826–1906), an American naval officer and scientist. He graduated from Annapolis; while in service at the Naval Observatory in Washington, he invented the deep-sea sounding apparatus which has since come into general use He was also the inventor of the Brooke gun and he designed the *Merrimac*.

93:21. Ehrenberg (1795–1876). A German naturalist, noted for his studies of *Infusoria*.

Bailey of West Point. Jacob Whitman Bailey (1811–1857). An American naturalist, a graduate of West Point, and afterwards professor of chemistry, geology, and mineralogy there. He was especially interested in microscopic studies, invented the Bailey indicator, and made many improvements in the microscope.

93:29. telegraph-cable. The first Atlantic cable was laid in 1858 by Cyrus W. Field, of New York. After a few weeks it ceased to act. In 1866 a permanent cable was laid.

95:4. Mont Blanc. Between France and Italy; the highest of the Alps, 15,781 feet above the sea.

96:24. Diatomaceæ. (Pronounced dī′ȧ-tō̇-mā′sē-ē.)

96:25. Radiolaria. (Pronounced rā′dĭ-ō̇-lā′rĭ-ȧ.)

98:13. Dr. Wallich. George Charles Wallich (1815–1899). An English scientist; he entered the Indian medical service in 1838. In 1860 he was attached to the *Bulldog* on her survey of

the Atlantic bottom for purposes of the proposed cable. For over twenty years he devoted himself to the study of marine biology. He published *Notes on the Presence of Animal Life in Vast Depths in the Ocean* and *The North Atlantic Sea-bed*. He received the medal of the Linnean Society for his researches.

98:19. **Mr. Sorby.** Henry Clifton Sorby, born in 1826. An English geologist; fellow of the Royal Society; elected President of Frith College, Sheffield, in 1882. (Lippincott, 1905.)

99:5. **Pyramids.** The tombs of the Egyptian Pharaohs, built of solid masonry in large blocks closely fitted, from about 2500 to 2000 B.C.

100:6. **Polyzoa.** (Pronounced pŏl'ĭ-zō'å.)

100:7. **Brachiopoda.** (Pronounced brăk'ĭ-op'ŏ-då.)

100:8. **Nautilus.** Cf. Holmes's poem, *The Chambered Nautilus*.

101:33–34. **Sir Charles Lyell.** (See note to p. 80, line 34, *A Liberal Education: and Where to Find It*.)

102:12. **Echinus.** (Pronounced ē-kī'nus.)

104:12. **the river Somme.** In the north of France. It flows into the English Channel thirty miles northeast of Dieppe.

104:22. **the chipped flints of Hoxne or of Amiens.** Hoxne, Suffolk, England; Amiens, department of the Somme, France. Here prehistoric relics, flint implements, also the bones of extinct animals were discovered as early as 1800.

105:26. **Rev. Mr. Gunn.** Robert Campbell Gunn (1808–1881). A British naturalist. He emigrated to Tasmania in 1829, where he became Superintendent of Convict Prisons. He was always interested in natural history and made collections of mammals, birds, reptiles, etc., which he sent to the British Museum. He was elected fellow of the Royal Society in 1854. He helped found the Royal Society of Tasmania.

105:33. **a writing upon the wall of cliffs at Cromer.** Cf. Daniel V, 5. "In the same hour came forth fingers of a man's hand, and wrote over against the candlestick upon the plaster of the wall of the king's palace; and the king saw the part of the hand that wrote."

106:5–6. **"the whirligig of time brought its revenges."** Cf. Twelfth Night, V, i, 379.

"The whirligig of time brings in his revenges."

106:33. **Euphrates and Hiddekel** (Tigris). Euphrates, the great river of Mesopotamia; Tigris, a river of Asiatic Turkey; it flows into the Euphrates.

107:8–9. "the great river, the river of Babylon." Cf. Psalms CXXXVII, 1 and Genesis XV, 18.

"By the rivers of Babylon, there we sat down, yea, we wept when we remembered Zion."—Psalms CXXXVII, 1.

". . . Unto thy seed have I given this land, from the river of Egypt unto the great river, the river Euphrates."—Genesis XV, 18.

107:26. Sinai and Ararat. Sinai, the main mountain group of the Sinaitic peninsula. The mountain, called also Horeb, on which the law was given to Moses. Ararat. A volcanic mountain in two summits, Great and Little Ararat, in Armenia. The traditional resting-place of Noah's Ark.

109:17. pterodactyl (tĕr'ō-dăk'tĭl). An extinct reptile.

ichthyosaurus (ĭk'thĭ-ō-sa̤'rus). A gigantic extinct marine fish-like reptile.

109:18. plesiosaurus (plē'sĭ ō-sa̤'rŭs). A genus of large extinct marine reptiles.

109:20. ammonites and belemnites. Am'monīte, the fossil shell of an extensive genus. Belem'nīte, the fossil bone or shell of an extinct mollusk. (See Huxley's essay, *On the Method of Zadig*, for an interesting description.)

110:9–10. hide its diminished head. Cf. Milton, *Paradise Lost*, Bk. IV, line 34.

> "At whose sight all the stars
> Hide their diminished heads."

110:12. Battle of Hastings. The battle was fought on a hill, Senlac, near Hastings, October 14, 1066. William the Conqueror defeated the English under Harold, who was slain in the battle.

110:13. Terebratulina caput serpentis. Tĕr'ē-brăt'ū-lā—the genus loosely known as lamp shells.

111:30–31. "older tertiary." Tertiary, third order or rank. In geologic time, the era following the mesozoic or secondary interval of time in the formation of the earth's crust.

113:6–7. "without haste, but without rest." Cf. Goethe, *Zahme Xenien*, II.

> "Wie das Gestirn
> Ohne Hast
> Aber ohne Rast
> Drehe sich, jeder
> Um die eigne Last."

VI. ON SCIENCE AND ART IN RELATION TO EDUCATION

115:4–5. those who were bidden to the feast in the Gospel. Cf. Matthew XXII, 2–10.

2. "The kingdom of heaven is like unto a certain King, which made a marriage for his son,

3. "And sent forth his servants to call them that were bidden to the wedding; and they would not come," etc.

115:19. Philomathic Society. Philomath—a lover of learning, a scholar. Philomathic Society, a society of learned men.

115:30. "Hansardisation." Hansard, an official report of proceedings in the British Parliament—so called from the name of the publishers.

117:11. Goths and Vandals. Ancient Teutonic races that plundered Rome in the fifth century.

117:21. Cerberus. The three-headed dog that guarded the entrance to the infernal regions. Hence, any vigilant custodian or guardian.

119:26–27. Mr. Worthington—one of the masters of Clifton. Clifton, a suburb of Bristol, England, and a famous watering place. It contains Clifton College, a noted educational institution.

121:24. Mr. Freeman. Edward Augustus Freeman (1823–1892), an eminent English historian; graduate of, and afterwards professor at, Oxford University. His most famous book is *The History of the Norman Conquest.*

122:5. the be-all and end-all. Cf. Macbeth I, vii, 1–7.

> "If it were done, when 'tis done, then 'twere well
> It were done quickly: if the assassination
> Could trammel up the consequence, and catch
> With his surcease, success; that but this blow
> Might be the be-all and the end-all here,
> But here, upon this bank and shoal of time,—
> We'd jump the life to come."

122:6. sine quâ non. An indispensable condition.

122:9. William Harvey. (See note to p. 25, line 5, *On the Educational Value of the Natural History Sciences.*)

124:11. **here comes the rub.** Cf. Hamlet III, i, 56–65.

"To be or not to be—that is the question:—
* * * * * * *
. . . To die;—to sleep;—
To sleep! perchance to dream:—ay, there's the rub."

124:28. **"the most favoured nation."** This is a phrase used in making international treaties. It indicates that the nation in question is to have all the rights and privileges granted any other in the particular point under consideration.

125:13. **Francis Bacon.** (See note to p. 42, line 15, *On the Adviseableness of Improving Natural Knowledge.*)

125:16. **Next to being right,** etc. Cf. Browning's poem, *The Statue and the Bust.*

127:11–12. **"harmony in grey."** Cf. Browning's *Andrea del Sarto.*

"There's what we painters call our harmony!
A common greyness silvers everything."

128:8. **Sebastian Bach.** Johann Sebastian Bach (1685–1750), one of the greatest German composers of church music. He also wrote much for the piano, his most famous works being his *Fugues.*

129:3. **Shakespeare, Goethe.** (See note to p. 72, lines 19, 20, *A Liberal Education: and Where to Find It.*)

133:19. **Chaucer.** (See note to p. 72, line 19, *A Liberal Education: and Where to Find It.*)

Milton. (See note to p. 41, line 11, *On the Adviseableness of Improving Natural Knowledge.*)

133:20. **Hobbes,** Thomas (1588–1679). A celebrated English philosopher. His most famous work is *Leviathan, or the Matter, Form, and Power of a Commonwealth, Ecclesiastical and Civil.*

Bishop Berkeley. George Berkeley (1685–1753). An Irish churchman of English descent, celebrated for his philosophical writings.

134:3–4. **as we have recently been furnished with in prose.** The first edition of Lang, Leaf, and Myers's translation of the *Iliad* appeared in 1882. This is probably what Huxley refers to.

135:4. **Locke,** John (1632–1704). One of the most celebrated of English thinkers and philosophers. His chief work is his *Essay Concerning Human Understanding.*

135:30. **Franciscus Bacon sic cogitavit.** Thus thought Francis Bacon.

VII. A LOBSTER: OR THE STUDY OF ZOÖLOGY

136: Prefatory Note.—Lines 1–2. **South Kensington Museum.** At first a large building of iron and wood, on ground acquired for the Exhibition of 1851. It was opened in 1857 as a collection of a scientific character from this exhibition; since superseded by the present permanent buildings. It is intended for the promotion of art and science by means of systematic training of competent teachers, the founding of schools of art, public examinations, the giving of prizes, establishment of art libraries, etc. The enormous natural history collection of the British Museum was in 1880 removed to a very handsome building in South Kensington, erected for the purpose, on the site of the Exhibition of 1862. It is one mile southwest of Hyde Park Corner. In 1899 Queen Victoria laid the foundation of additional buildings which double the area of the main building, and commanded that the name be changed to Victoria and Albert Museum which is now the official designation.

137:7. **Linnæus.** (See note to p. 11, line 21, *Autobiography.*)

155:22. **British Museum.** A celebrated museum in Great Russell Street, London, founded in 1753. It contains collections of prints, drawings, antiquities, and a library of 2,000,000 volumes, probably the best library in the world.

VIII. ON THE STUDY OF BIOLOGY

162:12. **neologism.** A new word or phrase.

162:30–31. **Bacon—Hobbes.** (See notes to p. 42, line 15, *On the Adviseableness of Improving Natural Knowledge,* and p. 133, line 20, *On Science and Art in Relation to Education.*)

163:11–12. **Royal Society.** (See note to p. 11, line 26, *Autobiography.*)

163:21. **"Principia"—Newton.** (See note to p. 17, line 23, *On the Educational Value of the National History Sciences.*)

164:22. **Buffon—Linnæus.** (See notes to p. 11, lines 17, 21, *Autobiography.*)

165:21. **"Ces deux,"** etc. These two kinds of organized beings (animals and plants) have many more traits in common than they have real differences.

165:34. **Bichat** (1771–1802). An eminent French anatomist and physiologist. His discoveries mark an epoch in the history of biology. He wrote *General Anatomy* and *Physiological Researches Concerning Life and Death.*

Lamarck (1744–1829). A celebrated French naturalist.

166:1. **Treviranus** (1776–1837). A German naturalist. His chief work is *Biologie, oder Philosophie der Lebenden Natur* (Biology, or the Philosophy of Living Nature.)

171:28. **Leibnitz** (1646–1716). A celebrated German philosopher and mathematician, the inventor of differential and integral calculus.

Bonnet (1720–1793). A Swiss naturalist and philosophical writer.

172:33. **Professor Allman.** George James Allman (1812–1898). A British zoölogist, regius (royal) professor of natural history in the University of Edinburgh, 1855–1870.

174:3. **cry of "wolf."** Cf. Æsop's Fable, *The Shepherd-Boy and the Wolf.*

174:6–8. **like the light given out by the crackling of thorns under a pot of which Solomon speaks.** Cf. Ecclesiastes, VII, 6.

"For as the crackling of thorns under a pot, so is the laughter of the fool: this also is vanity."

176:2. **Liebig** (1803–1873). A celebrated German chemist. He wrote *A Dictionary of Organic Chemistry* and *Organic Chemistry in its Application to Agriculture.*

176:23. **till the crack of doom.** Cf. Macbeth, IV, i, 117.

"What! will the line stretch out to the crack of doom?"

180:31. **"mighty maze without a plan."** Cf. Pope, *Essay on Man,* Epistle I, Line 1.

"Let us . . .

* * * * * * *

Expatiate free o'er all this scene of man
A mighty maze! but not without a plan."

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